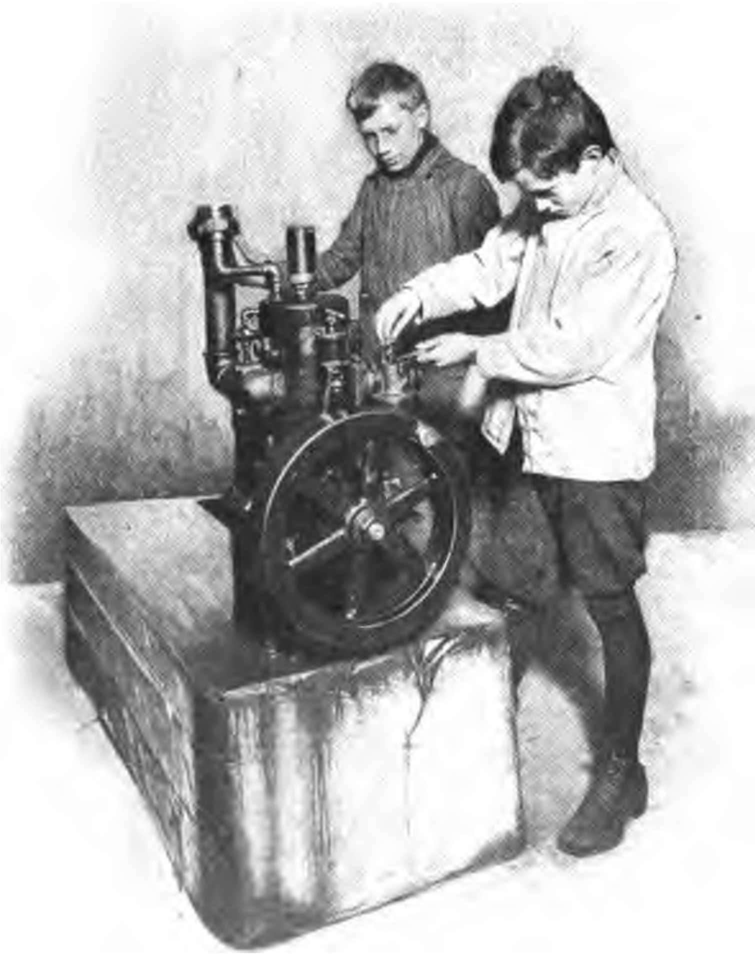
HARPER'S GASOLINE ENGINE BOOK



SETTING UP THEIR MOTOR

HARPER'S GASOLINE ENGINE BOOK

HOW THE ENGINE IS MADE
HOW TO USE IT AT HOME, IN
BOATS AND VEHICLES, AND
ELSEWHERE, AND HOW
TO KEEP IT IN ORDER

BY

A. HYATT VERRILL

AUTHOR OF
"HARPER'S WIRELESS BOOK"
"HARPER'S AIRCRAFT BOOK"

ILLUSTRATED FROM
DRAWINGS BY THE AUTHOR
AND PHOTOGRAPHS

HARPER & BROTHERS PUBLISHERS
NEW YORK AND LONDON
MCMXIV

PRINTED IN THE UNITED STATES OF AMERICA
PUBLISHED APRIL, 1914
D-O

CONTENTS

PAGE

INTRODUCTION xvii

Part I

THE GAS ENGINE

CHAPTER I—WHAT A GAS ENGINE IS 3
THE TWO-CYCLE MOTOR—PARTS OF THE TWO-CYCLE MOTOR

CHAPTER II—THE FOUR-CYCLE MOTOR 12
PARTS OF THE FOUR-CYCLE MOTOR—COMPARISON OF TWO AND FOUR STROKE MOTORS—PISTON-RINGS

CHAPTER III—KEEPING MOTORS COOL 20
AIR-COOLED MOTORS—WATER-COOLED MOTORS—CIRCULATING THE WATER—HOW MOTORS ARE OILED—FORCE-FEED OILERS

CHAPTER IV—WHAT MAKES THE POWER 34
FLOAT-FEED CARBURETERS—MECHANICAL VAPORIZERS—HOW THE GAS IS EXPLODED—THE JUMP-SPARK SYSTEM—THE MAKE-AND-BREAK SYSTEM

CHAPTER V—THE ELECTRICAL EQUIPMENT 46
SOURCES OF ELECTRICITY—SOME ELECTRICAL TERMS EXPLAINED—HOW BATTERIES AND MAGNETOS PRODUCE ELECTRICITY—MAGNETOS AND DYNAMOS—HIGH-TENSION MAGNETOS—SPARK-COILS—SPARK-COILS AND WIRING—SIMPLE WIRING

Part II

MOTOR ANATOMY

CHAPTER VI—SINGLE AND MULTIPLE CYLINDER MOTORS . . 73
CRANK-CASES—SHAFTS AND BEARINGS—VALVES—POSITION OF VALVES—FIRING SEQUENCE

CONTENTS

PAGE

CHAPTER VII—SPECIAL FORMS OF MOTORS 105

SLEEVE-VALVE MOTORS—ROTARY VALVES—ARRANGEMENT OF CYLINDERS—AEROPLANE MOTORS—THE ROTATING-MOTOR

CHAPTER VIII—SIZE AND POWER OF MOTORS 125

Part III

MARINE AND STATIONARY MOTORS

CHAPTER IX—THE MARINE MOTOR 133

SHAFTS AND UNIVERSALS—MUFFLERS AND SILENCERS—INSTALLATION OF MARINE MOTORS—CARE AND HANDLING OF MARINE MOTORS

CHAPTER X—STATIONARY MOTORS 153

GOVERNORS—POWER TRANSMISSION—INSTALLING STATIONARY MOTORS—TWO BOYS AND A MOTOR

Part IV

THE VEHICLE MOTOR

CHAPTER XI—AUTOMOBILES AND THEIR MOTORS 181

AUTOMOBILE MOTORS—AUTOMOBILE IGNITION—BREAKER ADJUSTMENTS—LOCATING IGNITION TROUBLES—CARBURETERS AND ADJUSTMENTS

CHAPTER XII—CLUTCHES, TRANSMISSIONS, ETC. 200

DIFFERENTIALS—BRAKES—BEARINGS AND AXLES—STEERING-GEAR

CHAPTER XIII—MOTOR-CYCLES AND CYCLE-CARS 224

CYCLE-CARS—TYPES OF CYCLE-CARS

Part V

TROUBLES AND REPAIRS

CHAPTER XIV—PREVENTING TROUBLES 237

OVERHAULING

CHAPTER XV.—TOOLS AND SUPPLIES 253

HANDY HINTS AND EMERGENCY REPAIRS

APPENDIX—MOTOR TROUBLES AND THEIR REMEDIES . . 263

TABLE OF TROUBLES AND THEIR REMEDIES 266

GLOSSARY OF TECHNICAL TERMS 277

INDEX 289

ILLUSTRATIONS

Setting up Their Motor . . . . *Frontispiece*

CHAPTER I

FIGURE PAGE
1. Operation of Two-cycle Motor 6
2. Operation of Two-cycle Motor 6
3. Operation of Two-cycle Motor 6
4. Operation of Two-cycle Motor 6
5. Operation of Three-port Motor 8
6. Operation of Three-port Motor 8
7. Operation of Three-port Motor with By-pass in Piston . . . 8
8. Air-cooled Two-cycle Motor Showing Various Parts 10

CHAPTER II

1. Operation of Four-cycle Motor 13
2. Operation of Four-cycle Motor 13
3. Operation of Four-cycle Motor 13
4. Operation of Four-cycle Motor 13
5. Four-cycle Motor with Mechanical Intake-valve 15
6. Four-cycle Motor Showing Various Parts 17
7. Two-cycle Motor 18
8. Four-cycle Motor 18
9. Piston and Piston-rings 19

CHAPTER III

1. Cooling-fan in Front of Motor 21
2. Cooling-fan Integral with Fly-wheel 21
3. Section of Water-cooled Cylinder Showing Jacket Cast Integral 22
4. Section of Water-cooled Cylinder Showing Separate Jacket Clamped on 22
5. Various Types of Radiators 23
6. Radiator with Water-tank Separate 23

ILLUSTRATIONS

FIGURE PAGE

7. Hopper System of Cooling by Water 25
8. Thermo-siphon System of Cooling 25
9. Rotary Pumps 25
10. Gear-pump 25
11. Plunger-pump 27
12. Lubrication by Mixing Oil with Fuel 27
13. Gravity-feed Oiler 31
14. Tank Gravity-feed Oiler 31
15. Force-feed Oiler 33
16. Gear-pump Force-feed Oiler 33

CHAPTER IV

1. Section of Generator Valve or Mixer 35
2. Schebler Model "D" Carbureter Showing Parts 35
3. One Form of Mixing-valve 40
4. Spark-plugs 40
5. Spark-plug in Position in Cylinder 40
6. A Simple Timer 40
7. Timer in Firing Position 40
8. Make-and-break Ignition System 43

CHAPTER V

1. Diagram of Direct Current 51
2. Diagram of Alternating Current 51
3. Section of a Dry Battery 53
4. Magnetic Field 53
5. Magnetic Field of a Coil 53
6. Section of a Magneto 55
7. Section of a Dynamo 55
8. Induction-coil 55
9. The Remy Breaker 55
10. A Box-coil 61
11. A Dash-coil 61
12. Make-and-break Coils 61
13. A Plug-coil 61
14. Diagram for Wiring 64
15. Diagram for Wiring 64
16. Diagram for Wiring 64
17. Diagram for Wiring 64
18. Diagram for Wiring 64
19. Diagram for Wiring 64

ILLUSTRATIONS

FIGURE | PAGE

20. Diagram for Wiring 65
21. Diagram for Wiring 65
22. Diagram for Wiring 65
23. Running Wires Through Tubes for Protection 65
24. Running Wires Under Clips 65
25. Tubes for Protecting Wires on Motors 67
26. Wires Held by Leather Strips 67
27. Wires Held by Staples 67
28. Various Forms of Wire Connectors 67

CHAPTER VI

1. Cylinder with Separate Head 75
2. Case with End-plates 75
3. Two-cycle Motor with Split Base 75
4. Four-cycle Motor with Split Base 75
5. Motor with Separate Cylinders 76
6. Cylinders in Pairs 76
7. Cylinders Cast "En Bloc" 76
8. Section of a Two-cycle Crank-case 78
9. Section of a Four-cycle Crank-case 78
10. Hand Hole in Base of Two-cycle Motor 79
11. Hand Hole and Plate on Two-cycle Motor 79
12. Hand Hole and Plate on Four-cycle Motor 79
13. Case with Lower Half Removable 79
14. Lower Half of Case Removed 80
15. Two-cylinder Shaft with Two Bearings 82
16. Four-cylinder Shaft with Five Bearings 82
17. Three-cylinder Two-cycle Motor Bearings 82
18. Bearing-caps in Position 82
19. Bearings Showing Space for Shims 82
20. Bearings with Shims 82
21. Fastening Methods for Studs and Nuts 84
22. Piston-pin Bushed in Piston 84
23. Piston-pin Bushed in Connecting-rod 84
24. Set-screw Fastened by a Wire 84
25. Set-screw Fastened by Lock-nut 84
26. Roller-bearings 86
27. Ball-bearings 86
28. Poppet-valves and Parts 87
29. Spur-gears 89
30. Skew-toothed Gears 89
31. Worm or Screw Gears 89

FIGURE PAGE
32. Sprocket and Chain 89
33. Cam-gear Driven Direct 89
34. Cam-gear Driven by Idler 89
35. Piston and Valves, Relative Position 91
36. Piston and Valves, Relative Position 91
37. Piston and Valves, Relative Position 91
38. Timing Marks on Fly-wheel 91
39. Valve Positions 93
40. Rocker-arms for Operating Overhead Valves 93
41. Lag of Spark 95
42. Advancing Spark 95
43. Firing Sequence 98
44. Firing Sequence, 1, 2, 3, 4 99
45. Two-cylinder Four-cycle Motor Firing Alternately 101
46. Firing Sequence of Two-cylinder Opposed Motor 103
47. Dead-centers on a Single-cylinder Motor 104
48. Three-throw Crank without Dead-centers 104
49. Counterweights 104

CHAPTER VII

1. Gray Two and Three Port Motor 106
2. Detroit Two and Three Port Motor 106
3. Open-base Two-cycle Motor 106
4. Section of Sleeve-valve Motor 108
5. Section of Sleeve-valve Motor 108
6. Section of Sleeve-valve Motor 108
7. Section of Sleeve-valve Motor 108
8. Section of Piston-valve Motor 110
9. Section of Piston-valve Motor 110
10. Section of Piston-valve Motor 110
11. The Reynolds Motor 112
12. Two-cycle Rotary-valve Motor 114
13. Portion of the Elmore Motor 114
14. Vertical Form of Motor 115
15. Opposed Form of Motor 116
16. V Form of Motor 116
17. Radial Form of Motor 117
18. Diagrammatic View of Vertical Motor Showing Length of Case 118
19. Diagrammatic View of V-form Motor Showing Length of Case 118
20. Diagrammatic View of Opposed Motor Showing Length of Case 118
21. Diagrammatic View of Star Motor Showing Length of Case 118
22. Diagrammatic View of Radial Motor Showing Length of Case 118

ILLUSTRATIONS

FIGURE		PAGE
23.	Gnome Rotating-motor	121
24.	Section of the Gyro Motor	123
25.	Section of Cylinder of Gyro Motor	123
26.	Trebert Rotating-motor	124

CHAPTER IX

1.	Section of a Planetary Marine Gear	135
2.	Joe's Marine Gear	135
3.	A One-way Clutch	135
4.	Simple Universal Joint	138
5.	Sleeve and Flange Couplings	138
6.	Perforated-tube Muffler	141
7.	Baffle-plate Muffler	141
8.	Yankee Muffler	141
9.	Ejector Muffler	141
10.	The Hydrex Silencer	142
11.	Thermex Silencer	142
12.	Installation of Exhaust in a Boat	144
13.	Installation of Fuel-pipe in a Boat	146
14.	Details of Bed for a Round-bottomed Boat	146
15.	Details of Bed for a Flat-bottomed Boat	146

CHAPTER X

1.	Hit-or-miss Governor	155
2.	Cam-operated Governor	156
3.	Sliding-sleeve Governor	156
4.	Throttling Governor	156
5.	Pulley and Belt Transmission	156
6.	Varying-speed Transmission	159
7.	Train of Pulleys	159
8.	How to Line Up Pulleys	159
9.	Tight and Loose Pulleys	163
10.	Belt Arranged to Reverse Motion	163
11.	Belt-guides	164, 165
12.	Belt-fasteners	166
13.	Belt-lacings	166
14.	Belt-stretchers	166
15.	Exhaust-silencer Made from Barrel	166
16.	Sections of Concrete Beds	168
17.	A Stationary Motor on Skids and Trucks	170

ILLUSTRATIONS

CHAPTER XI

FIGURE — PAGE

* Plate Showing Various Parts of an Automobile Motor . . . 183
1. Bosch Magneto Breaker 187
2. Remy Magneto Breaker 189
3. Remy Distributer 190
4. Arrangement of Wires for Firing 1, 3, 4, 2, Right or Left Hand Rotation 191

* Plate Showing Various Parts of Automobile Requiring Lubrication 193

5. Guarding High-tension Wires 195
6. Various Standard Carbureters 197

CHAPTER XII

1. Planetary Automobile Transmission Gear 200
2. Positions of Lever with Progressive-gear Shift 200
3. * Selective-gear Shift 202

* Plate Showing Parts of Automobile Chassis 204

4. Various Positions for Gear Shifting 207
5. A Cone-clutch 207
6. A Metal-disk Clutch 207
7. Friction-drive Transmission 207
8. Friction-drive on Center 207
9. Friction-drive on Left 207
10. Turning a Corner 210
11. A Spur-gear Differential 210
12. A Bevel-gear Differential 210
13. * Brake Construction 212
14. Annular and Cone Ball-bearings 214
15. Types of Roller-bearings 216
16. Forms of Rear-axle Construction 217

17 A. * Worm and Sector Steering-post 219

17 B. Rack-and-pinion Steering-gear 219

17 C. Ball-and-socket Joints for Steering-gear 219

18. Steering-knuckles and Forks 220
19. How to Line Up the Front Wheels 221

CHAPTER XIII

1. Cranks of Iver Johnson Motor-cycle 225
2. Valve Action of Iver Johnson Motor-cycle 225

† The Convenience of the Cycle-car 227

† The Imp Cycle-car 229

ILLUSTRATIONS

FIGURE PAGE
The Twombly Cycle-car 230
3. Spring Assembly of Imp Cycle-car 231
4. † Motor of the Imp Cycle-car 232
5. Steering-gear of the Imp Cycle-car 233

CHAPTER XIV

Overhauling a Motor 241
1. * Marking Gears 243
2. Marking Magneto Shaft and Couplings 244
3. Tagging Wires and Connections 244
4. McQuaid Piston-rings 245
5. Placing Rings on a Piston 246
6. Rings Locked in Position by Pins 246
7. Wedges and Strips for Placing Pistons in Cylinders 247
8. Valve-lifters 248
9. Home-made Valve-grinding Tool 249
10. Exhaust-gaskets 249

CHAPTER XV

1. Splitting a Worn Bolt to Make It Hold 258
2. How to Dip Gasoline with a Valve-cap or Envelope 258
3. To Use a Monkey-wrench for Pipe 258

* Permission of Willys-Overland Company.
† Permission of W. H. McIntyre Company.

INTRODUCTION

THE advent of the successful gas engine revolutionized mechanical progress, and by its aid we have attained many of our most wonderful and important inventions and accomplishments.

It has made possible the aeroplane and the submarine, the automobile, the motorcycle, and the motor-boat. In factories, farms, and homes countless motors are in daily use, steadily and rapidly performing a thousand tasks that formerly required the slow and laborious work of many hands. Gas engines even drive the great dynamos that flash unseen wireless messages across the broad Atlantic, while locomotives thunder across continents and steamships plow the seas by means of this same wonderful power.

The modern gas motor is the simplest, strongest, and most compact power-producing device known to man, and yet not one person in a thousand has but a vague idea of its principles or operation.

The purpose of this book is to serve as a simple, practical, and complete guide for all those who own, use, or operate gas and gasoline motors. In its preparation every effort has been made to do away with technical terms and names and to adapt the book to the requirements of those who possess little or no knowledge of engineering or mechanics. While intended primarily for boys, yet it will prove of equal

value for older readers, as it is more complete and exhaustive than any book on the subject hitherto published, aside from strictly technical works. The author, who has had many years' experience with gasoline motors of all types, has substituted facts for theories and has included a vast amount of useful information, handy hints, and valuable suggestions which have proved of actual practical value in connection with gas-engine work. As the number of gasoline engines is increasing daily and there are now over ten thousand motor manufacturers in the United States it is impossible to describe or even mention more than a limited number of the various motors in use. As far as possible all the principal and distinct types have been included and described as well as the more important or useful accessories, appliances, and fittings used in connection with motors.

While the principles of all gas engines are similar, yet the motors designed for a certain use differ considerably from those designed for some other purpose. In this book the marine, stationary, vehicle, and aeroplane motors have each been treated and described in separate chapters in addition to the clear and simple description of the principles, operation, and construction of motors in general.

The reader interested in some particular kind of motor can at once turn to the chapter dealing with this form without being obliged to read through the text relating to motors of other types.

To the uninitiated the gasoline engine appears very complicated, but in reality it is a very simple machine and any intelligent boy may easily master its principles, construction, and care. Every owner or operator of a motor should be thoroughly familiar with every detail of its mechanism and should be competent to make his own repairs and adjustments. In this way a great deal of time, trouble, and

expense may be saved and the pleasure of driving a car or operating a motor-boat will be vastly increased.

While motors are now remarkably efficient and reliable, yet they are far from perfection, and the boy with a mechanical mind will find in the gas engine great opportunities for his inventive genius and experiments.

Aside from the explanatory descriptions of the principles, operation, and construction of motors a great deal of space has been devoted to motor troubles and repairs. By its alphabetical arrangement this part of the book has been greatly simplified, and by referring to it almost any ordinary trouble may be located and remedied by an amateur. This is a most valuable and practical feature of the book, for it shows exactly what to do and how to do it when the occasion arises.

The value of any book treating of a mechanical subject is greatly enhanced by clear and simple diagrams and illustrations, and in this respect the present work excels all others of its kind.

The illustrations are nearly all original, and in their preparation the author has made no attempt to produce accurate scale or working drawings; the object being to furnish diagrammatic cuts which will clearly and simply accentuate the more important points described in the text.

The automobile, the motor-boat, and the aeroplane are each subjects for a special treatise and cannot be fully dealt with in a book devoted to motors. Many of the parts and appliances used in these modern vehicles of land, water, and air are, however, very closely related to the motor itself. In such cases the parts directly affecting, or affected by, the operation of the motor have been described and explained. In treating such subjects well-recognized and widely used types have been selected, as several volumes would be

required to describe in detail each of the innumerable forms of gears, shafts, clutches, transmissions, and similar devices in every-day use.

Every boy who is interested in motors or motor vehicles and who wants to know "what makes the wheels go round" will find the answer in this book. Those who are more advanced and wish to know *how* to make the wheels go and how to keep them going will find herein the information they seek, and those who already know both the *why* and *how* may add still more to their knowledge by a perusal of the following pages.

Part I

THE GAS ENGINE

HARPER'S GASOLINE ENGINE BOOK

Chapter I

WHAT A GAS ENGINE IS

LET us begin by recalling how much the gas engine does. This wonderfully efficient, compact, light, and powerful motor drives mills and factories, plows the fields, reaps the crops, threshes the grain and grinds the flour, churns the butter and pumps the water on thousands of farms. It saws the wood, operates mills, and hoists the logs in far-off lumber camps. It drives air-compressors and drills, and lifts the ore and men in mines. On every road and thoroughfare trucks, busses, and pleasure vehicles pass and repass, all driven by this same power, while harbors, rivers, and even the broad oceans are navigated by craft of every size and for every purpose propelled by gas engines.

More wonderful yet, this same simple and inconspicuous motor has enabled us to conquer the air and the depths of the sea, and by its aid submarines dive and navigate far beneath the surface of the water, while graceful aeroplanes traverse the air thousands of feet above the earth.

No modern invention has played a more important part in our commercial and mechanical progress than the gas engine, or has been more rapidly improved and adapted to universal use.

While extremely simple in construction and operation, yet the gas engine appears a mysterious and complicated apparatus to many, and comparatively few people really know how a gas engine works, what it really is, or why it is able to develop enormous power from a little gasoline and an electrical spark.

The term "gas engine" covers a great many types and forms of motors, for in a broad sense all motors that utilize oil, kerosene, gasoline, or gas for fuel are gas engines, or, better, "internal-combustion engines." The principles of all are similar, and an explanation of one will serve as an explanation of any of the various forms of internal-combustion motors.

A gas engine is any kind of a motor in which a charge of gas is exploded within a tight chamber, and which derives its power from the force of the exploding gas.

In a way the internal-combustion engine operates much like a cannon, for the cylinder corresponds to the barrel, and the piston takes the place of the ball, and, as a matter of fact, the original ancestor of all gas engines was designed to be operated by exploding gunpowder.

We can all realize what an enormous amount of power could be obtained from the ball driven from a cannon by exploding powder if we could but control its force. In the modern gas engine this terrific power of expanding gases is brought under control and compelled to work at the will of man.

In the steam engine we must burn fuel to heat water, which in turn is transformed to steam, and the expanding steam is led into a cylinder where it operates a piston. All this roundabout wasteful process is eliminated in the gas engine, for the burning fuel itself drives the piston direct and is transformed into power with but little waste energy. For this reason the gas engine is the most economical form of engine known; and, as no boiler, furnace, or other cum-

bersome parts are required, it is the most compact of all engines.

Although all gas engines operate on the same basic principle, yet they vary wonderfully in detail and in methods and design; but, nevertheless, every kind, type, make, or form of gas engine may be referred to one of two general types, or forms known as "two-cycle" and "four-cycle" motors.[1]

The Two-Cycle Motor

The simplest form of gas engine is the two-cycle or two-stroke motor. This type is free from valves, cams, springs, and a great many other parts found in many gas engines, and in its simplest form it may have as few as *three moving parts*.

Although generally known as the "two-cycle motor," yet this term is apt to be confusing to those unfamiliar with mechanics and engineering, and for that reason the term "two-stroke" motor is preferable.

In this form of motor the piston receives an explosive impulse or power stroke on every revolution of the crankshaft, or on every *two strokes* of the piston, whereas in the "four-cycle" or "four-stroke" type the explosive impulse occurs on every other revolution, or on every *four strokes* of the piston.

A very simple form of two-stroke motor is illustrated in Figs. 1, 2, 3, 4. In Fig. 1 the motor is shown in section, with the piston A at the extreme bottom of the stroke. The engine-base B is connected through suitable apparatus

[1] Certain motors of the six-cycle type have been built and used to some extent, but they are so seldom seen or used that they are not deemed worthy of a detailed description. In these motors the additional idle stroke is used to draw a charge of air into the cylinder in order to thoroughly cleanse it of burnt gas and also as an aid to cooling.

(to be described later) with the fuel supply at the opening C, which is provided with a check-valve (D), which opens inward but not outward.

If the piston A is moved upward in the cylinder E by turning the crank-shaft F, the piston will act like a pump,

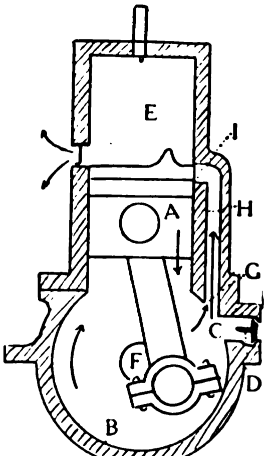


Fig. 1

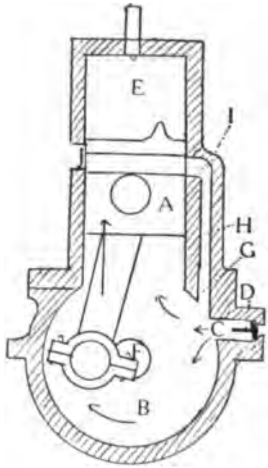


Fig. 2

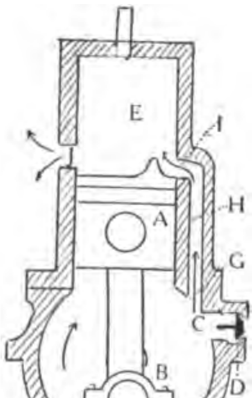


Fig. 3

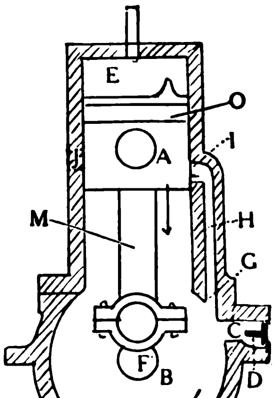


Fig. 4

and will draw a charge of gas, or fuel, into the base through the opening and check-valve D, as shown in Fig. 2. If the revolution of the crank-shaft is continued the piston will move downward, and, as the gas in the base cannot escape through the check-valve D, it is forced upward through the opening, or "port," G and the by-pass H until the downward-moving piston uncovers the upper port or opening I, whereupon the gas rushes into the cylinder above the piston, as shown in Fig. 3. The crank-shaft, continuing to revolve, again forces the piston upward, compressing the gas in the firing-chamber, or top of the cylinder, and at the same time pumping a fresh charge of fuel into the base (Fig. 4).

It is at this point, with the piston at the upward limit of its stroke, that the compressed gas in the cylinder is ignited by an electrical spark. The compressed gas instantly explodes, forcing down the piston until the opening J is exposed, when the burnt gas rushes out to the open air, and the fresh fuel in the base rushes in to take its place through the port I. The momentum of the fly-wheel and crank-shaft carries the piston upward again, another spark ignites the new charge, and the entire operation is repeated over and over again as long as fuel is furnished and the spark ignites it.

From the above explanation and the illustrations it will be seen that the operation of the two-stroke motor consists of but *two cycles*, the *compression-stroke* (Fig. 2) and the *firing-stroke* (Fig. 3).

This particular kind of two-stroke motor is known as the "*two-port*," and there are various other types which operate in a similar manner with minor variations. The most important of these is the "*three-port*" motor, which is illustrated in Figs. 5 and 6. In this form there is no check-valve in the base, but in its place there is a third port (K),

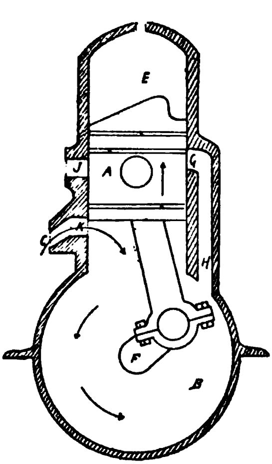


Fig. 5

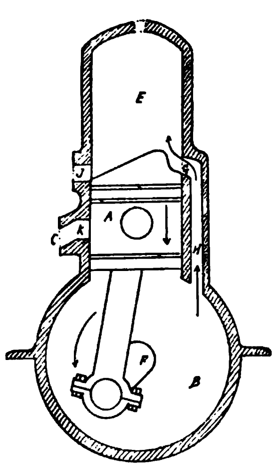


Fig. 6

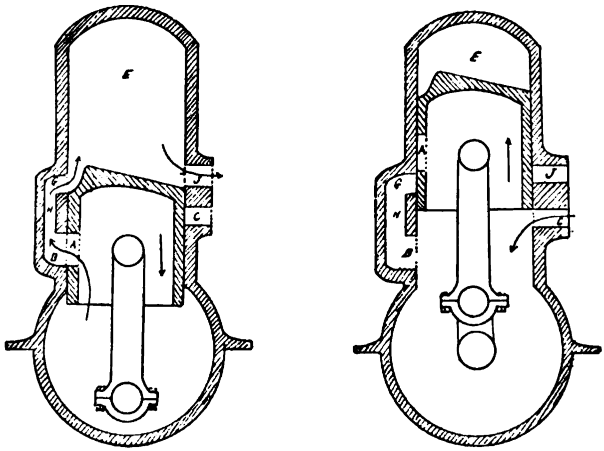


Fig. 7

which is opened and closed by the piston, which thus acts as a check-valve. Aside from this the principles of its operation are very similar to the two-port motor already described.

In Fig. 5 the motor is shown with the piston commencing

its upward or suction stroke, with the gas rushing into the base through the intake C, but instead of being sucked into the base directly, as in the two-port type, the fuel is drawn by the vacuum created by the piston before the third port opens. As the piston descends this third port is closed by the piston, as shown in Fig. 6, and the fuel is forced upward through the by-pass and port G-H, as in the two-port type. The firing then takes place, and the burnt gases escape as already described.

Some forms of three-port motors have an opening in the piston, and another in the cylinder-wall instead of the by-pass G-H. A motor of this type is illustrated in Fig. 7. By this arrangement there is no possibility of the gas in the base reaching the top of the cylinder too soon, for it cannot enter the firing-chamber until the opening A and the by-pass opening B are exactly in line, as indicated in the diagram.

Parts of the Two-Cycle Motor

By looking at the diagrams shown in Figs. 1 to 7 it will be seen that the essential parts of the two-cycle motor are few in number, consisting of a cylinder E, the crank-case B, piston A, connecting-rod M, crank-shaft F, piston-pin N, and piston-rings O. These are really all the parts there are to the motor proper; but in addition numerous appliances, attachments, and accessories are required in order to create a spark at the proper instant for igniting the charge, to mix the fuel and carry it to the motor, to keep the moving parts oiled, etc.

A great many of these parts are on the outside of the motor, and no two motors are exactly alike in this respect, for some builders make their motors as simple as possible and get along with the barest necessities, while others add

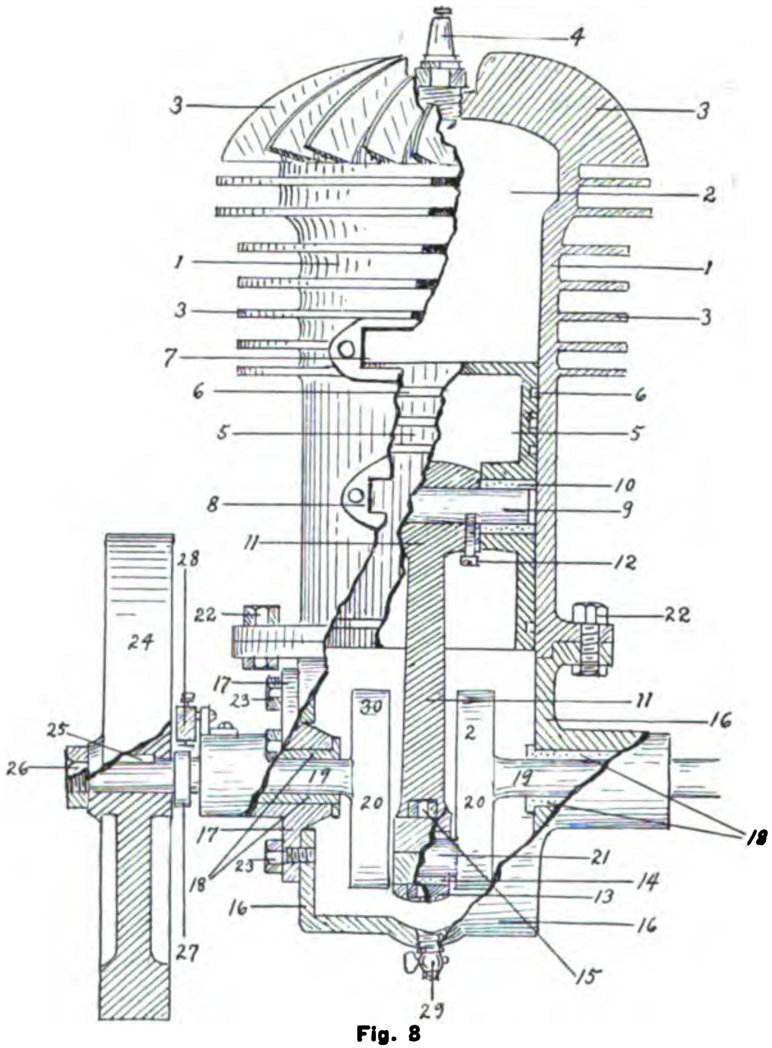


Fig. 8

PARTS OF TWO-CYCLE MOTOR

1 = Cylinder
2 = Firing-chamber
3 = Cooling-flanges
4 = Spark-plug
5 = Piston
6 = Piston-rings
7 = Exhaust-port
8 = Inlet-port
9 = Piston-pin
10 = Piston-pin bearings
11 = Connecting-rod
12 = Piston-pin set-screw
13 = Connecting-rod cap
14 = Connecting-rod bearings
15 = Connecting-rod cap-bolts
16 = Crank-case
17 = Crank-case end-plate
18 = Main-bearings
19 = Crank-shaft
20 = Crank
21 = Crank-pin
22 = Cylinder-flange bolt
23 = End-plate bolt
24 = Fly-wheel
25 = Fly-wheel key
26 = Fly-wheel nut
27 = Timer-cam
28 = Timer
29 = Drain-cock
30 = Counter-balance

all sorts of attachments, some of which are an advantage, but many of which are merely added in order to make the motor appear more complicated and of greater value.

A simple two-cycle motor showing all the essential parts is illustrated in Fig. 8, in which the engine is represented with a portion of the cylinder cut away to show the internal mechanism. This is the simplest type of gas engine it is possible to devise, and is of the two-cycle, three-port type, air-cooled. As the apparatus for creating the spark, the carbureter, or fuel-mixing device, and various other accessories are identical in both two and four stroke motors, a detailed description of these will be left until after we master the principle and operation of the four-stroke motor.

Chapter II

THE FOUR-CYCLE MOTOR

THE four-cycle or four-stroke motor is also known as the "Otto-cycle," as the first really successful motor of this type was the "Otto gas engine." Motors of this kind are more widely used in motor-vehicles than are two-stroke motors; but for marine use the two-cycle is more often used than the four-stroke, especially in small or medium sizes. In mechanical movements and parts the four-stroke motor is far more complicated than the two-cycle; but, nevertheless, it is much simpler and easier to construct a good and efficient four-stroke motor than one of the two-stroke type.

In Figs. 1 to 4 sections of a simple form of four-stroke motor are shown. In Fig. 1 the engine is illustrated with the piston A at the top of the stroke and ready to descend. In this position the inlet-valve C and the exhaust-valve D are both closed. As the piston descends the inlet-valve opens, owing to the suction exerted by the descending piston being greater than the tension of the spring G, and through this opening the fuel is drawn until the cylinder above the piston is filled. At this point, indicated in Fig. 2, the piston commences to ascend again, and, the suction being released, the spring immediately closes the inlet-valve, thus preventing the gas from escaping. As the piston continues on its upward stroke the charge of gas is compressed until the

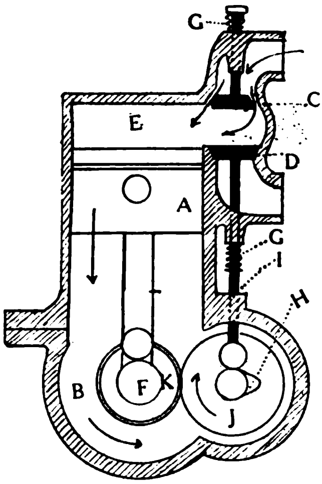


Fig. 1

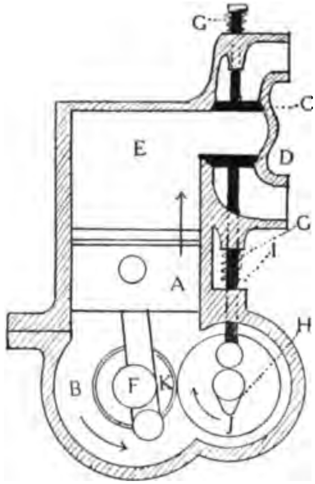


Fig. 2

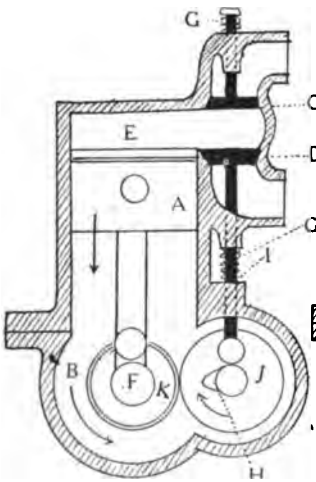


Fig. 3

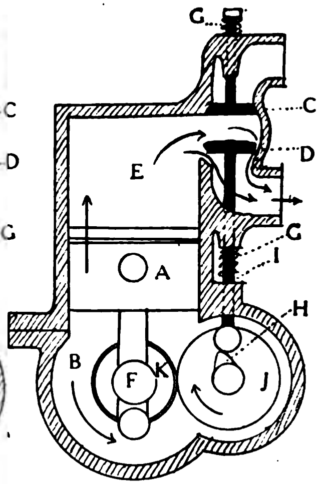


Fig. 4

FOUR-CYCLE-MOTOR OPERATION

piston attains the upward limit of its stroke (Fig. 3); when a spark is created, the charge is exploded and the piston is driven down. At the extreme downward limit of this firing-stroke (Fig. 4) the exhaust-valve D is opened by a rod actuated by the cam H, and the burnt gas is forced out through the valve as the piston again travels upward (Fig. 4). At the upward limit of this *fourth* stroke the engine again assumes the position of Fig. 1, and is ready to receive a fresh charge of gas.

From this explanation and the figures it will be seen that in this motor an impulse, or explosion, occurs only on *every other* downward stroke of the piston; or, in other words, *four* strokes are necessary to complete one cycle of operations. Thus there is an *intake-stroke*, a *compression-stroke*, a *firing-stroke*, and an *exhaust-stroke*.

Parts of the Four-Cycle Motor

If you will compare the diagram of the two-stroke motor (Chapter I, Fig. 1) with the illustration of the four-stroke motor (Chapter II, Fig. 1) you will see that the latter has a great many more parts than the former. Some of the parts, such as the piston, piston-rings, cylinder-base, crank-case, piston-pin, and crank-shaft, are common to both motors; but in addition to these the four-stroke motor has an *intake-valve* C, an *exhaust-valve* D, the *cam* H, *push-rod* I, *valve-springs* G,G, a *cam-gear* J, and the *driving-gear* K.

Although the particular form of four-stroke motor illustrated has an intake-valve which opens by the suction of the downward-moving piston, the majority of four-cycle motors have a *mechanically operated* intake-valve which is opened by a cam and push-rod like the exhaust-valve. A

view of this kind of motor is shown in Fig. 5. Such a device requires an intake-valve, push-rod, and cam in addition to the parts already enumerated.

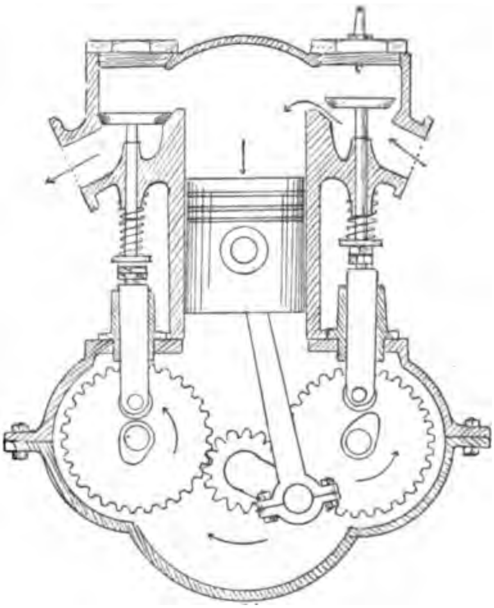


Fig. 5

These are merely the most vital or essential parts, and, like the two-stroke motors, the four-cycle engine must be equipped with a carbureter, ignition apparatus, cooling devices, oiling systems, etc.

A simple air-cooled four-stroke motor with mechanically operated valves is illustrated in Fig. 6, with a portion cut away so as to show both internal and external parts.

Comparison of Two and Four Stroke Motors

At first thought one would suppose that the very simple two-stroke motor, receiving an explosive impulse at each revolution, would develop far more power and would be more reliable than the four-stroke motor with its numerous parts and an impulse on every other revolution. Oddly enough, this is not the case, and most four-cycle motors are more reliable than the two-cycle kind, and also develop more power than two-stroke motors of the same size (Figs. 7 and 8).

This is due to several causes. In the first place, it is far more difficult to build a good two-cycle motor than a four-cycle, for the parts must be more accurately fitted, the base must be absolutely tight, and the intake and exhaust ports very carefully designed and proportioned in order to operate successfully. The two-cycle motor is also a great deal more susceptible to changes in fuel and to the proportions of fuel than the four-stroke engine. The latter may be operated on widely varying fuels, and the base may be perfectly open. And the adjustment of the valves is easily regulated so that they open more or less, as required, or early or late, as related to the revolution of the shaft. In this way minor faults in design or proportions may be overcome, and it is therefore easier and cheaper to build the four-stroke than the two-stroke motor. Why the four-cycle type should develop more power in proportion than the two-cycle is something of a mystery, but even the very best two-cycle motors do not develop appreciably more power than four-cycle motors of the same size. Two-stroke motors do run more evenly and with less vibration than four-stroke motors, for the latter must be equipped with a very heavy fly-wheel in order to give the shaft momentum sufficient to carry the crank, piston, and connecting-rod through the idle strokes. Unless it is very carefully balanced this heavy wheel causes the engine to shake and vibrate, and therefore small motors of the single-cylinder type are more often of the two-cycle than of the four-cycle construction.

Piston-Rings

In the foregoing pages the piston and piston-rings have been mentioned, and, as these are very important parts of the motor and must be understood in order to appreciate

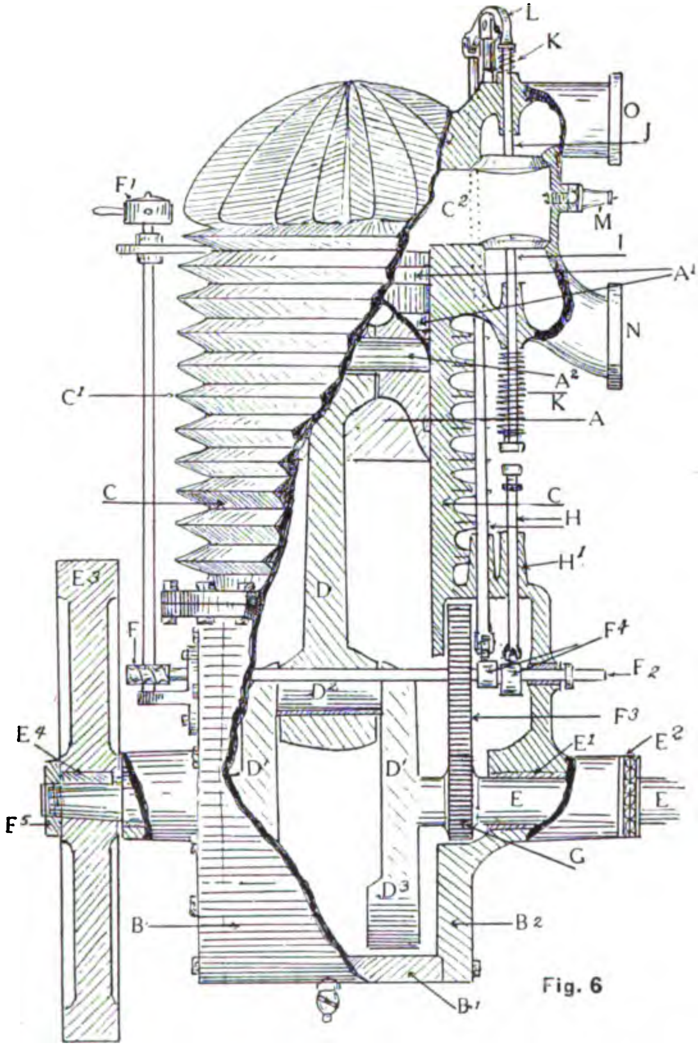


Fig. 6

A = Piston
A 1 = Piston-rings
A 2 = Piston-pin
B = Base, or crank-case
B 1 = Base-plate
B 2 = End-plate
C = Cylinder
C 1 = Cooling-fins
C 2 = Firing-chamber
D = Connecting-rod
D 1 = Crank
D 2 = Crank-pin
D 3 = Counterweights
E = Shaft
E 1 = Shaft-bearings
E 2 = Ball-thrust
E 3 = Fly-wheel
E 4 = Key
E 5 = Fly-wheel nut
F = Timer-gears
F 1 = Timer
F 2 = Cam-shaft
F 3 = Cam-shaft gear
F 4 = Cams
G = Driving-gear
H = Push-rods
H 1 = Push-rod guides
I = Inlet-valve
J = Exhaust-valve
K = Valve-springs
L = Rocker-arm
M = Spark-plug
N = Intake
O = Exhaust

the functions and principles of other parts and appliances, a little explanation may make their purpose plain.

The piston slides up and down in the cylinder, and it must move readily and smoothly, and yet be tight enough

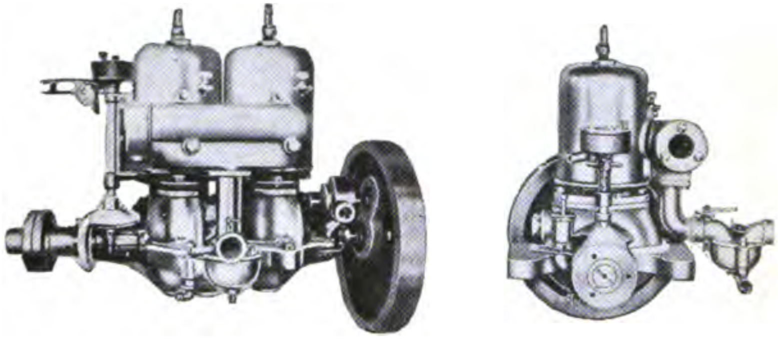


Fig. 7
TWO-CYCLE MOTOR

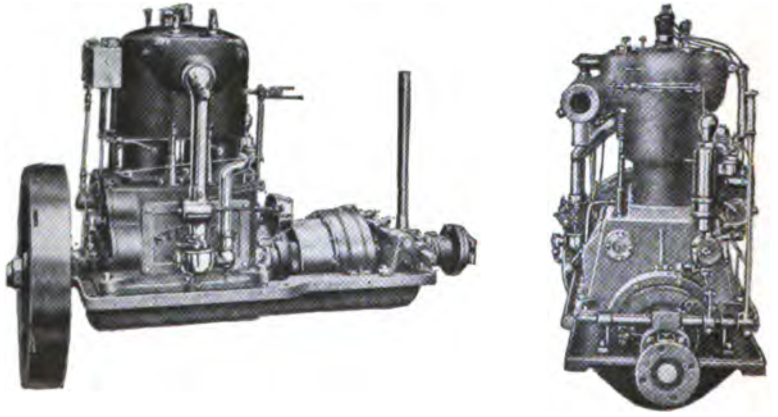


Fig. 8
FOUR-CYCLE MOTOR

to prevent the gas from leaking between it and the cylinder-walls, even when under the terrific force of the explosion. It would be practically impossible to make a plain piston

which would fulfil these requirements, for if it was tight enough to hold the exploding gas, it would bind and stick as soon as it became hot and expanded with the heat. To overcome this difficulty all gas-engine pistons are equipped with *piston-rings* (Fig. 9). These are cast-iron rings open at one side and fitting into grooves cut in the piston. Piston-rings are made slightly larger in diameter than the inside of the cylinder, so that when they are forced into the cylinder their natural elasticity keeps them pressed firmly against the cylinder-walls, thus preventing the gas from leaking past them, and at the same time allowing the piston to move readily in the cylinder.

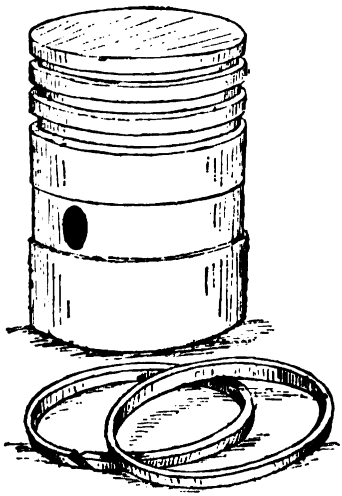


Fig. 9

Chapter III

KEEPING MOTORS COOL

AS the exploding or burning gas in a motor creates an enormous amount of heat, and as this extremely high temperature would soon warp and injure the cylinder and piston and ruin the motor, provision must be made to keep the engine at a normal and even temperature. Several methods are employed for accomplishing this, the principal ones being *air-cooling*, *water-cooling*, and *oil-cooling*. As the last method is used on comparatively few engines, and generally on those of the stationary class, we may confine our attention to the air and water cooling systems, especially as cooling by oil is very similar in operation and mechanisms to water-cooling.

Air-Cooled Motors

Air-cooling is the simplest of all systems, and is widely used on motors for automobiles, aeroplanes, and motor-cycles, as well as on stationary engines.

In order to cool a motor by this method the exterior of the cylinder is formed with projecting flanges, or "fins," of thin metal to radiate the heat, and to still further cool the metal a fan is usually provided which forces a constant stream of air over the motor. The fan may be either a revolving fan placed in front of the motor and operated by a belt or gears from the shaft (Fig. 1), or it may be in the form

of a fly-wheel containing blades and placed in the rear of the motor, where it draws the heated air away from the motor and thus allows fresh, cool air to reach it (Fig. 2). In order to insure a still more positive circulation of air some motors are inclosed within a tunnel or cylinder of metal through which the air is forced. This system is em-

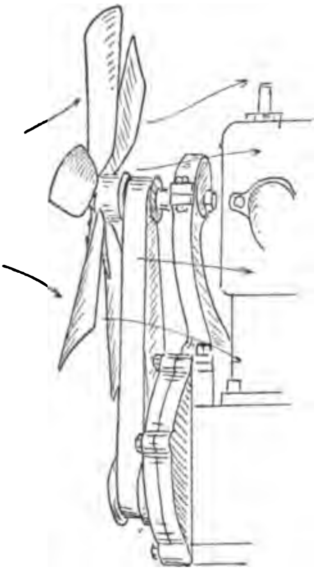


Fig. 1

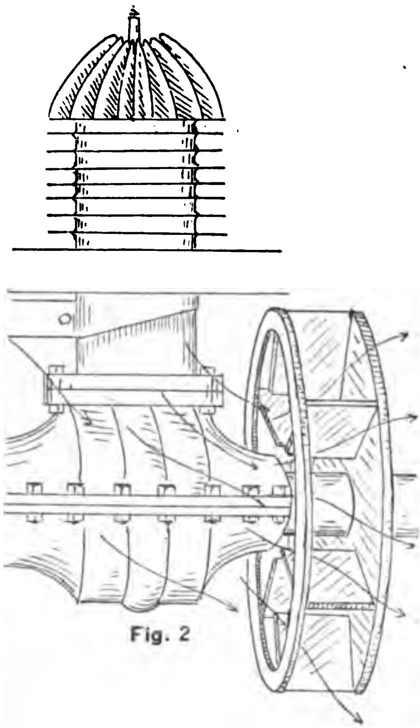


Fig. 2

ployed in many splendid motors, among them the Renault, which has proved very efficient in both motor-vehicles and aircraft.

Water-Cooled Motors

Whereas the air-cooled motors depend upon a draught of air to keep them cool, and the system is therefore very simple,

water-cooled motors require a number of special parts and mechanisms to insure adequate cooling. In this type of motor the cylinders are surrounded with a thin outer cover-

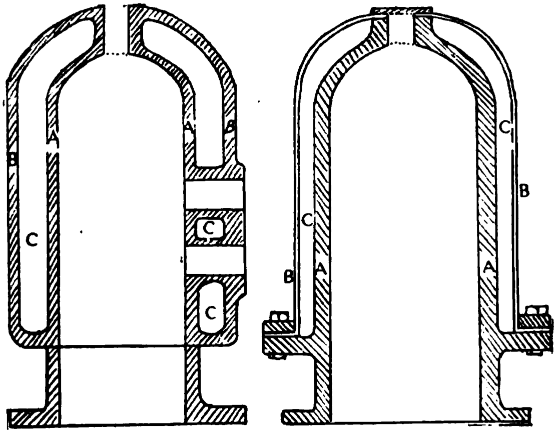


Fig. 3 Fig. 4

ing, or shell, known as a water-jacket, with a space between it and the cylinder. A section of a cylinder of this kind is shown in Fig. 3, in which A represents the cylinder-wall, B the jacket, and C the water-space between the two.

Sometimes the jacket is cast of iron as a part of the cylinder itself, while other motors have the jacket made of thin copper or brass and clamped on over the cylinders, as illustrated in Fig. 4. In either case the idea is to provide a layer of water around the cylinders to absorb the heat.

Of course, if this water remained stationary, it would soon become boiling hot, and would be transformed to steam and would no longer serve to cool the engine. To avoid this, means are provided to keep the water constantly circulating or moving through the jacket-space, and, as even when thus moving the water would soon become very hot, an appliance for rapidly cooling the water must be added to the

equipment. Such appliances are known as radiators or "hoppers."

Radiators are usually employed on motor-vehicles, while hoppers are used on stationary motors. Radiators are merely thin metal tubes so constructed as to present the greatest possible surface to the air, and they are made in a great variety of patterns. Some of the best and most common forms are shown in Fig. 5. A is a simple tubular radiator, in which the copper tubes are covered with thin flanges, or disks, of metal for radiating the heat; B is a

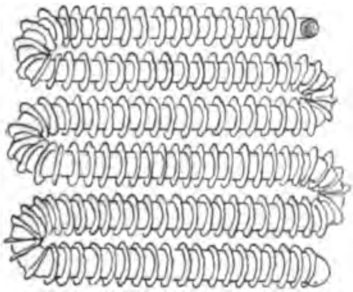


Fig. 5 A

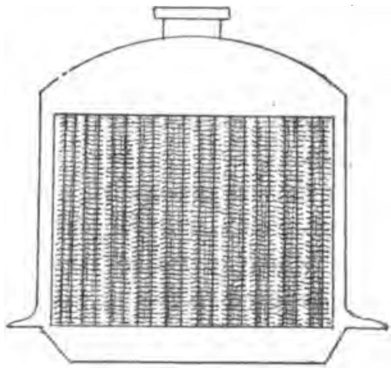


Fig. 5 B

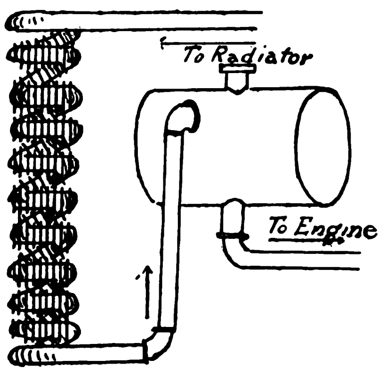


Fig. 6

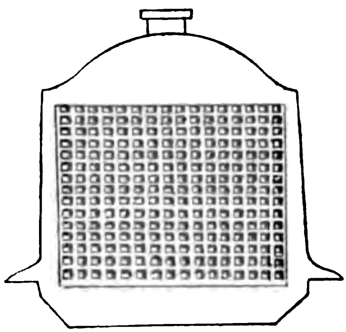


Fig. 5 C

radiator composed of tubes connected at top and bottom with water-spaces, and provided with radiating flanges; while C is a "cellular" type of radiator in which the tubes are formed into little squares of metal which serve to radiate the heat without additional flanges.

In any of these systems the water contained in the tubes would not be sufficient in quantity to cool the motor, and a reservoir of some sort must be added in order to provide an ample amount of water to cool the motor. In the forms shown in Fig. 5, B and C, the upper portion of the radiator itself acts as a reservoir, but in the type shown at A a separate tank is placed near the radiator, and the water is led from this through the radiator and hence around the cylinders and back to the tank, as indicated by the arrows in Fig. 6.

In the hopper-cooled engines the tank is merely an open receptacle from which the water flows around the cylinders, after which it is discharged over a screen or roughened surface exposed to the air, as illustrated in Fig. 7.

Circulating the Water

To keep the water continually in motion and circulating about the cylinders and through the radiator two systems are in common use. One of these is known as the *thermo-siphon*, and depends solely upon the fact that hot water rises and cold water sinks. By placing the radiator at the proper level in relation to the engine, and using a large tube at the top and a smaller one at the bottom, the water as it becomes heated rises to the top of the cylinders, and, as it is continually pressed up from beneath by the cold water in the radiator sinking down, the warm water is forced up through the tube A (Fig. 8) into the top of the radiator. As

it gradually cools off in the radiator it settles down and is constantly being replaced by the warmer water from the cylinders, so that there is a slow but steady circulation of water, as indicated by the arrows.

A commoner and more reliable means of circulating the water is to use a power-pump of some sort. Most modern

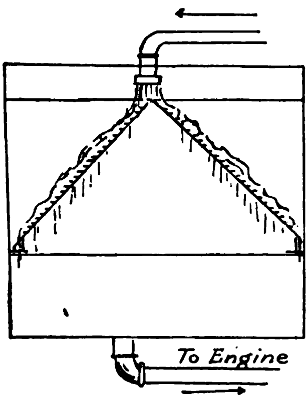


Fig. 7

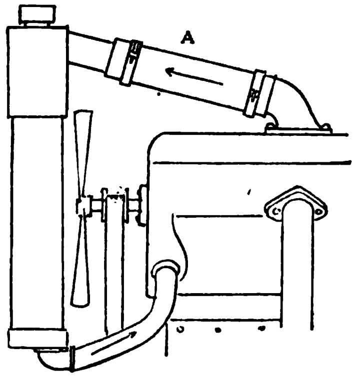


Fig. 8

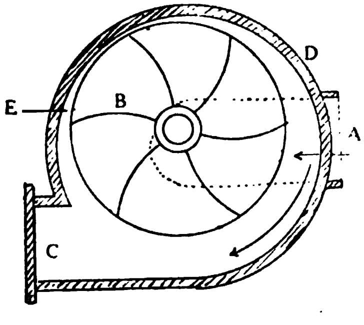


Fig. 9

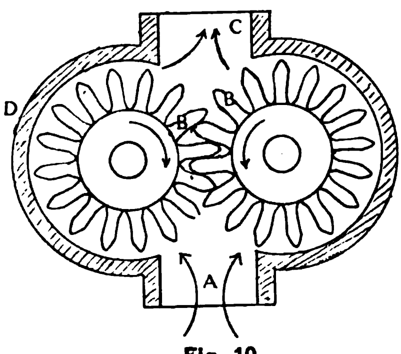


Fig. 10

gas engines are provided with a rotary or gear pump for this purpose. These are small, compact pumps of very simple design operated by a convenient gear or shaft on the

motor, and as they operate faster when the motor speeds up and slower as the motor speed decreases, the volume of water forced about the cylinders varies in exact proportion to the motor's needs.

Several forms of such pumps are in use, and some of these are shown in Figs. 9 and 10. Fig. 9 is a very simple rotary pump which is exactly like a small turbine water-wheel reversed. The water enters through A, and the revolving blades B throw it outward and force it through the opening C. You will notice that the wheel with the blades is not set exactly in the center of the case D, but a little to one side, so that the space at the outlet C is wider than just about it (E). If the space was of the same size all around, the wheel would revolve without forcing the water through the outlet, but as it reaches the narrow portion at E it cannot pass readily, and so rushes out through C.

This is a true rotary or centrifugal pump, but it is not nearly so powerful or positive as another form known as a gear-pump, and which is illustrated in Fig. 10. In this form of pump the water enters at A, and is at once seized by the rapidly revolving gears B, B, and is forced around between the teeth until they mesh together on the opposite side at C. As the water cannot flow back against the motion of the gears, and as it cannot find space between the intermeshing gear-teeth, it is forced out through the opening at D with considerable force.

These are the pumps usually employed in motor-vehicles, but for marine engines common plunger-pumps are often used. These are very different in operation, and one is shown in section in Fig. 11. In this type of pump the water is drawn into the chamber A by the suction of the piston, or plunger, B. The inlet C is provided with a check-valve D, which allows the water to run in the direction of the arrows

only, and the outlet E is also equipped with a check-valve which permits the water to flow only as indicated. As the plunger ascends in the chamber, or barrel, A the water is

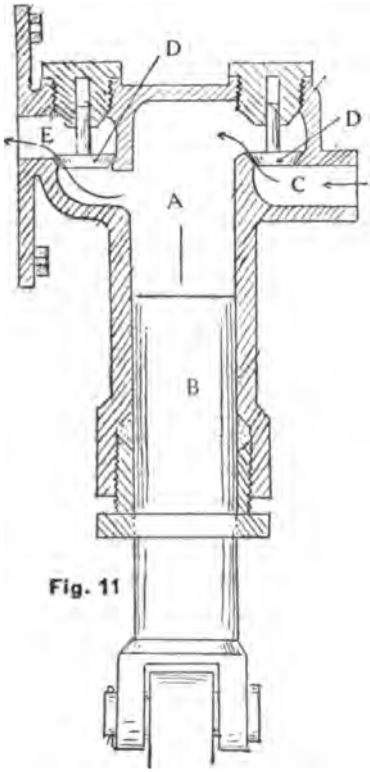


Fig. 11

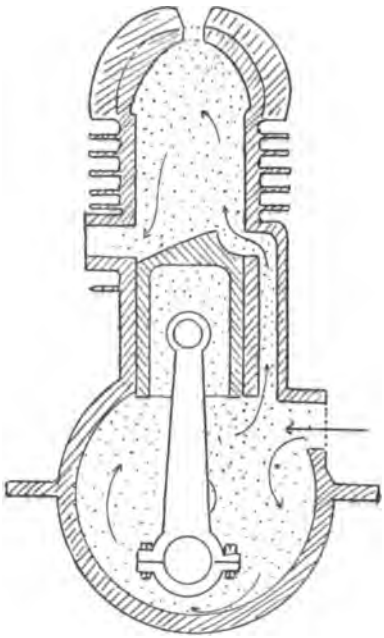


Fig. 12

forced up through E to the cylinders, and on the succeeding downward stroke more water is drawn in through D to be forced out through E on the following upward stroke.

These pumps are very positive in their action, but they usually leak more or less around the packing of the plunger, and they require considerable power to operate them, and, moreover, they do not pump a great volume of water rapidly. For this reason they cannot be used to advantage

in automobiles. On boats, where no radiators are required and an ample supply of water is always available, they answer very well indeed, and are widely used. They are more apt to become clogged by bits of sand, lint, etc., than the rotary or gear pumps, and for that reason a great many boats use the latter style of pumps.

Even when equipped with a good radiator and a powerful pump most engines will overheat, and to keep the water at a uniform and proper temperature fans are provided for circulating air about the radiator and motor. These fans are identical in design and operation with those used on air-cooled motors, so you can readily understand how much lighter and simpler an air-cooled motor must be than a water-cooled motor with its radiator, tank, pump, pipes, and water, not to mention the water-jackets and connections. Unfortunately, it is difficult to design an air-cooled motor that will work as well as a water-cooled engine, and for that reason far more water-cooled motors than air-cooled motors are used, as the additional weight and complications are more than offset by the even temperature and positive cooling of the water-cooled types.

How Motors Are Oiled

Like every piece of machinery, gas engines must be oiled or lubricated wherever there is a moving part. Many places on a gas engine are just as easily lubricated as a steam engine or any other machine; but the internal parts —the piston, valves, crank, connecting-rods, and bearings— are very difficult to lubricate properly, and require especially designed oiling devices and special oils.

The burning gases in the cylinder create a tremendously high temperature which would instantly burn ordinary

oils, and only purely mineral oils of the highest fire test are suitable for lubricating gas engines.

To feed the oil to the parts exposed to heat in positive and ample quantities is a problem which has been solved in a variety of ways; and, as the lubricating system of a gas engine is of vital importance, every person who uses or owns one should be thoroughly familiar with the oiling appliances and the effect of lubrication or lack of lubrication on his motor.

A great many people have an idea that as long as an abundance of oil is fed there is no danger; but in reality too much oil is almost as bad for a motor as too little. Insufficient oil will cause a motor to bind, and this will create an enormous amount of friction which will rapidly heat and cut the metal or even melt out the bearings. Too much oil will prevent the friction and wear, it is true; but, on the other hand, it will accumulate and gum up the motor, and will form carbon deposits in the cylinders and valves, and in time it will cause considerable damage and a lot of trouble. Just the proper amount of the right kind of oil must be fed in order to insure a smooth-running engine and freedom from troubles and repair bills, and to accomplish this great care must be given to the oiling devices.

Most engines are provided with mechanical oilers of some sort; but many marine engines, and some vehicle engines of the two-cycle type, are oiled by having the oil mixed with the fuel. When this is done little attention is required, except to see that the proper amount of oil is always added to any gasoline placed in the tank, and also to take care to oil all external parts, for of course the oil in the fuel only reaches the internal parts of the motor.

When oil of the proper kind is mixed with gasoline it apparently dissolves, but in reality it is held in suspension in

minute globules or drops. These drops of oil are carried into the motor when it is running, and as the gasoline vaporizes the oil is left behind adhering to the cylinder-walls, pistons, crank-bearings, etc. This method of oiling succeeds very well indeed in two-cycle motors if just the right amount of oil is added to the fuel. Too little oil will cause the motor to bind, while too much will cause the engine to gum up and smoke outrageously. Usually about a quart of oil is added to five gallons of fuel, and the oil *must* be added to the fuel and thoroughly mixed before placing it in the tank. If the fuel is placed in the tank and the oil added, it will result in poor lubrication, and in addition the oil will sink to the bottom and accumulate, or even choke up the carbureter.

By referring to Fig. 12 it will be seen that the parts of the motor requiring lubrication are kept constantly bathed in oil by this method, as indicated by the dots representing drops of oil and the arrows showing the flow of fuel. For four-cycle motors this system is not practical, for the oil accumulates in the firing-chamber, top of cylinder, and around the valves, where it is not required, and it does not reach the shaft-bearings, pistons, or cylinder-walls, where it is necessary. The author has found that excellent results are obtained by using a very little oil in the fuel of four-cycle motors. This will often improve their operation, but great care must be used not to use too much—half a pint of oil to five gallons of fuel is ample—for the oil thus used is merely auxiliary to the regular lubricating system.

Some motors of the smaller and cheaper types and a great many of the larger marine engines are equipped with "gravity"-feed oilers. These may be very simple affairs like the one shown in Fig. 13, or they may be more elaborate affairs such as the one illustrated in Fig. 14. In either case

the system consists of a reservoir (or cup) A, containing the oil, and so arranged that the oil drips into the tube (B) leading to the part to be lubricated. In order to insure the proper flow of oil in small drops, a check-valve (C) is provided, and the pressure of the air or gas in the cylinder of the motor or the suction of the moving parts forces the oil to drip slowly through the check-valve each time the pressure lifts

Fig. 13

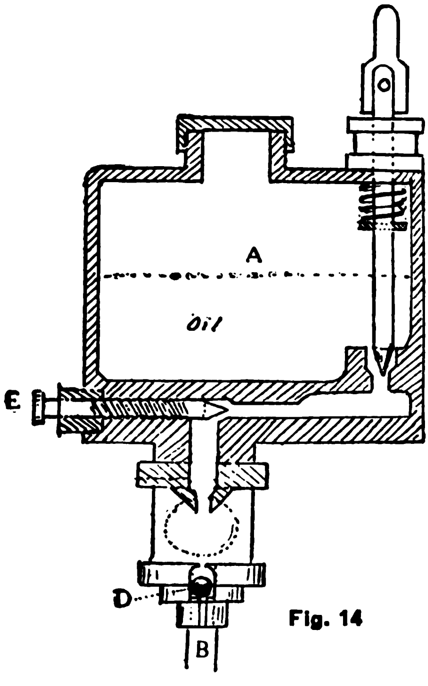


Fig. 14

the little ball D. To regulate the flow of oil a needle-valve (E) is provided so that more or less oil may be fed as required.

For some parts of a motor such oilers answer every purpose, but they must be constantly watched, kept filled with oil, and adjusted from time to time, to be sure that not too much or too little oil is reaching the motor.

Force-Feed Oilers

The surest and most satisfactory method of lubricating a gas engine is by one of the "force-feed" systems. By this method oil is forced from a reservoir through pipes leading to the engine by means of a pump, and the majority of modern motors employ this method in one form or another.

One style of force-feed oiler is illustrated in Fig. 15, where the container (A) is provided with a small pump (B), which is actuated by a shaft (C) connected with the motor. The oil is forced from the pump to the feed D, which leads the lubricant through pipes to the parts of the motor requiring lubrication.

Such oilers operate very satisfactorily, for the amount of oil forced through the pipes increases with the speed of the motor and in exact proportion to its requirements. On the other hand, the oil must constantly be replenished as it is used up, and for that reason systems in which the oil is constantly used over and over again are preferable, and most of the better vehicle motors are equipped with such systems.

These are very simple, and consist of a small gear-pump located in or near the crank-case and operated by positive gears (Fig. 16). The crank-case B also serves as a reservoir for the oil, and is provided with a secondary chamber (C) to which the pump is connected. In operation the pump draws up the oil from the reservoir C and forces it through oil-pipes and ducts to every bearing and moving part on the motor. After passing through the motor the oil drips back to the crank-case, and hence passes through strainers to the pump again.

As the level of the oil in the crank-case remains practically constant, the cranks and connecting-rods dip into the oil at each stroke, as illustrated at E, and splash it up against

the cylinder-walls and over the revolving crank-shaft and other internal parts. Many motors even have the crank-shaft, cam-shaft, connecting-rods, etc., bored from end to

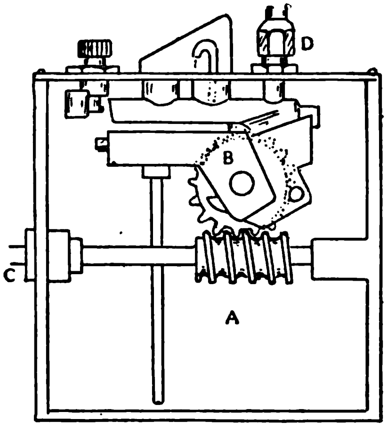


Fig. 15

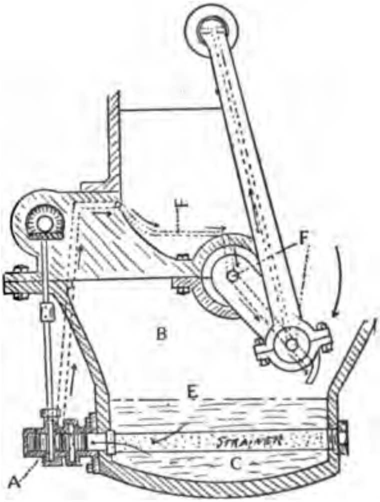


Fig. 16

end and connected with little openings, so that the oil is forced direct to every bearing, as shown at F.

By this method very little oil is wasted, and the oil reaches every part of the motor; and, as the force of the pump is considerable, there is little danger of the oil failing to flow through the pipes.

Such a system requires but little care, and, aside from attending to the proper amount of oil being placed in the crank-case from time to time, practically no attention need be given the oiling system. As a rule, gages or sight-feeds of some sort are always furnished with all force-feed systems, as some oil is consumed and must be replaced; but with any reasonable care there is little excuse for any one having trouble with such a lubricating system.

Chapter IV

WHAT MAKES THE POWER

THE term "gas engine" covers a great many radically different kinds of motors using a great variety of fuels, for in a way all these are really gas engines, whether the fuel is gasoline, kerosene, alcohol, gas, or oil, for in order to use any of these fuels the liquid must be transformed into gas before the charge is ignited.

True "gas engines" use coal-gas, natural gas, or producer-gas, for fuel, and there are many minor differences between these and the gas engines which use gasoline or other liquid fuels.

The majority of motors used in vehicles, boats, and for other commercial purposes burn kerosene or gasoline; but these substances must always be transformed to a volatile gas before the fuel will operate the motor or develop power. In order to accomplish this it is necessary to mix the fuel with a certain proportion of air, and this is done by passing the liquid through a device known as a *vaporizer* or *carbureter*.

There are a great many kinds of carbureters, some very simple and some very complicated; but the purpose of each and every one is merely to combine air and liquid in the proper proportions to form a highly explosive and inflammable gas.

In its simplest form a carbureter consists of a small open-

ing through which the liquid fuel passes, and a larger opening through which the air is drawn. Such a carbureter, or *mixing-valve*, is illustrated in Fig. 1. In this device A is the fuel-inlet with an adjustable needle-valve (B) to regulate the flow; C is the air-intake, with a spring check-valve (D), and E is the inlet to the motor.

The suction of the motor causes the check-valve D to lift from its seat, and a small quantity of fuel flows out through B, and the inrushing air passing over this immediately draws it up and vaporizes it and carries it into the motor. As the suction of the piston ceases and the downward stroke commences, the spring closes the air-valve and the entrance to the fuel-pipe, and any liquid adhering to the valve-seat is spattered over the interior surface ready to be vaporized on the next intake-stroke.

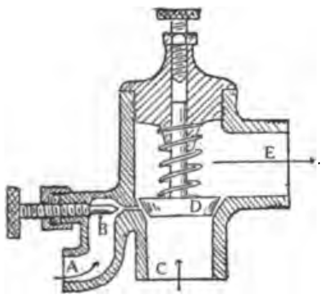


Fig. 1

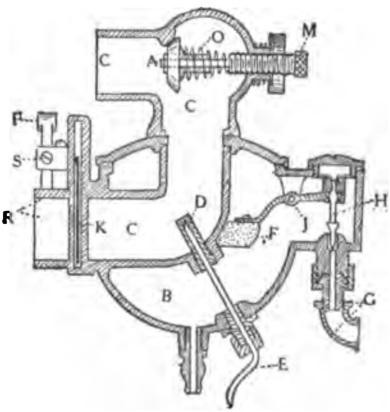


Fig. 2

By adjusting the needle-valve to admit more or less fuel and the check-valve to admit more or less air the proportions of air and liquid fuel may be varied to form the most explosive and economical gas possible.

Although such mixers work fairly well on small and sim-

ple motors, they are wasteful of fuel, and the proportions of air and fuel do not vary automatically with the speed or requirements of the motor. For these reasons they have been generally discarded in favor of more complicated mixing devices known as *float-feed carbureters.*

There are a great many of these carbureters made, and the majority are highly efficient and satisfactory. To describe every one in detail would require a special treatise, and, as the principle and operation of all are more or less similar, an explanation of one of the leading types is sufficient.

Float-Feed Carbureters

One of the simplest and most widely used float-feed carbureters is the Schebler. This is made in a variety of patterns, each with minor variations to suit different types of motors; but the simplest form, known as "Model D," illustrated in Fig. 2, will serve to illustrate the principle of all.

In this diagram R represents the inlet to the motor, G the fuel-pipe, D-E the needle-valve, and C the air-inlet. The lower portion of this carbureter is in the form of a bowl known as a float-chamber (B), and within this a cork float (F) is placed. This float is hinged or pivoted at J, and is connected by an arm to a needle-valve (H). When the fuel is turned on it flows through G and fills the bowl until the float F rises to the proper level. As soon as the float reaches this point the valve H shuts off the opening and prevents any more fuel from entering the bowl. As long as the motor remains inactive the gasoline in the float-chamber remains at the same level, but as soon as any fuel is drawn into the motor the float drops slightly and allows more fuel to flow in and keep the level constant.

When the piston of the engine moves on the suction or

intake stroke a current of air is drawn through the air-intake C and across the needle-valve D to the motor-inlet at R. This air rushing by the needle-valve draws a small quantity of the fuel from the opening in the needle-valve and vaporizes it to form a gas. As soon as the motor operates more rapidly a stronger suction of air is created, and more fuel is drawn from the needle-valve, and if the air opening remained of the same size this would result in an excess of fuel in proportion to the air, and would form a gas too "rich" to produce much power. To overcome this trouble a valve (A) is provided which is kept pressed lightly against its seat by a spring (O). With the increase of the suction of the air this valve is drawn back, allowing more air to pass through, and in this way the proportion of air and fuel varies in proportion to the speed of the motor. In order to regulate the amount of fuel and the quantity of air to suit motors of varying sizes, speeds, and designs the needle-valve and air-valve are furnished with adjusting devices. The needle-valve may be opened or closed by turning the handle E to right or left, and the air-valve may be adjusted by the thumb-nut M. By turning this to right or left more or less pressure is brought on the spring O, and consequently more or less air is admitted as required.

In addition to these adjustments there is a throttle-valve (K) operated by the lever P, which shuts off all or a part of the gas entering the motor. The lever may be readily adjusted by the set-screw S, so that the valve will not close completely, but will admit just enough gas to operate the motor very slowly.

Mechanical Vaporizers

Still another type of mixing device which is used to some extent and was formerly used on a great many motors is

known as a *mechanical mixing-valve.* A form that is still used on some motors is illustrated in Fig. 3. In this cut the inlet to the motor is shown at A, with the fuel-inlet at B, the air-intake at C, and the needle-valve at D. The needle-valve is attached to a thin, circular metal plate, or diaphragm, E, which fits over the air-passage and closes it when the motor is at rest. As soon as suction occurs the diaphragm is lifted and a small quantity of fuel is thus admitted through the needle-valve and combines with the inrushing air. To regulate the amount of fuel the disk E may be adjusted to raise more or less by tightening or loosening the screw G, which bears upon a flat spring (I). This spring presses upon the end of the needle-valve stem D, and by tightening or loosening the screw more or less tension is exerted by the spring, thus permitting the diaphragm and needle-valve to raise from its seat just the proper distance to produce the best mixture. When correctly adjusted such devices give very good results, but they are not very "flexible"; or, in other words, they do not respond quickly to the varying demands of motors which are operated at widely varying speeds, as are automobile, motorcycle, and other vehicle motors. For stationary engines that run at a constant speed they serve very well; but they are very easily affected by atmospheric conditions and require frequent adjustment.

The carbureter of a motor is a very delicate and sensitive piece of mechanism, and, once adjusted, it should never be altered or tampered with until you are positive that any trouble you may have lies in the carbureter.

No matter how good a motor you may own, or how carefully you may care for it, you will never have satisfactory results without a good carbureter properly adjusted. With modern carbureters very little trouble is encountered, and,

once adjusted, there is no reason why the carbureter should be disturbed in any way unless a different grade of fuel is used or the motor itself is altered or changed.

How the Gas Is Exploded

The gas or fuel used in a motor has no power to operate it unless the gas is burned or exploded, and to accomplish this in such a way as to produce the quickest and most violent combustion at precisely the right moment is by no means a simple matter.

In the older motors various devices, such as tiny flames, red-hot tubes, etc., were employed; but in the modern motors these clumsy methods have been superseded by the electrical spark.[1]

Even with electrical devices there are many difficulties to be overcome, for the ignition apparatus must be positive; it must create an intensely hot spark at exactly the right instant; it must be positive and reliable, and in addition it must be able to withstand the intense heat of the burning gases. Modern ignition systems may be divided into two general classes, the *jump-spark* and the *make-and-break* systems. The former is most widely used, and is probably the most satisfactory and reliable, although each method has its good points not possessed by the other. In the jump-spark system the electrical apparatus is complicated, but the mechanical parts are few and simple,

[1] A very different system of ignition is employed in certain forms of internal-combustion engines such as the Diesel. In these motors the charge of fuel is forced into the cylinders by a fuel-pump, and the compression of the charge is so great that the heat generated actually ignites it. These motors are started by turning the crank-shafts by letting compressed air into the cylinders, as the extremely high compression renders them very difficult to start in any other way.

whereas in the make-and-break system the mechanical parts are complicated and the electrical apparatus simple.

In either case the electricity used may be furnished by batteries or a magneto, and the purpose of each is merely to create a spark at the moment when the charge of gas is

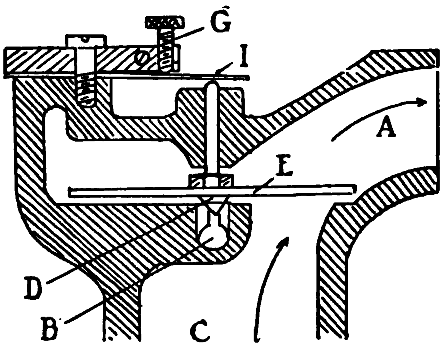


Fig. 3

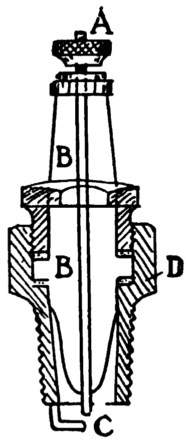


Fig. 4

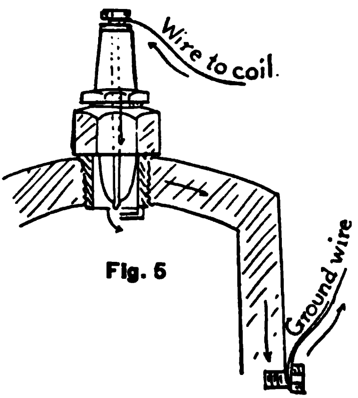


Fig. 5

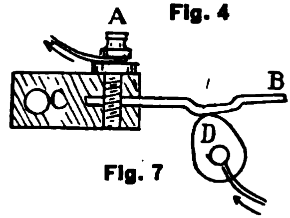


Fig. 7

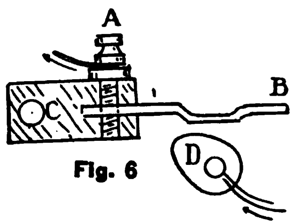


Fig. 6

compressed and ready to explode, and the efficiency of either system depends upon the heat, size, and rapidity of the spark produced.

The Jump-Spark System

This system consists of four essential parts: the *batteries* or *magneto* to furnish the current, the *spark-coil*, the *spark-plug*, and the *timer*. The spark-plug of the jump-spark system (Fig. 4) is a device consisting of a terminal (A) passing through a porcelain or mica core (B), and ending in an isolated point (C). The core is surrounded at its lower end with a collar, or bushing, of metal (D), which screws into the cylinder with the terminal C projecting inside.

To the upper end of the terminal A is attached the wire from the spark-coil, with the other wires properly connected to the battery or magneto, and the ground-wire fastened to some portion of the engine (Fig. 5). As the inner end of the terminal C is close to the metal shell D, the current from the coil has a tendency to "jump," or bridge over, the intervening space in order to find its way back to the ground. If the current was allowed to flow through the wires in this way, however, there would be a steady stream of sparks occurring at the gap, and the electricity would be wasted and the sparks would ignite the charge of gas before it was compressed and ready to be exploded in the cylinder.

In order to regulate the sparks so that they will occur at the right moment and will not waste the current a device known as a "timer" is used.

Timers are of many types and designs, and they vary from very simple devices to others quite complicated and delicate. The principle of all is the same, and the simplest ones are the easiest to understand, and for explanatory purposes the very simple device shown in Fig. 6 will answer every purpose. In this timer the ground-wire is fastened to the engine-frame through which the cam D passes, while the other wire is attached to the thumb-screw A on the

spring B. This spring and screw are insulated from the engine by means of a fiber block (C), so that the electrical current cannot pass from A to F. The cam D is connected with the valve-gear shaft, or to a special shaft so arranged that it will assume the position shown in Fig. 7 just at the instant when the charge should be ignited. As soon as it reaches this position it presses against the spring B, a connection is made through the wires, a spark occurs in the cylinder, and the gas is exploded. During the rest of the revolutions of the motor the cam does *not* touch the spring, and therefore no spark is formed in the cylinder. In a way the timer is a sort of revolving switch which is placed in such a position in relation to the motor that it connects the wires when the charge is to be ignited, but keeps them separated at all other times.

The Make-and-Break System

This is a system of ignition used more often on marine or stationary motors than on motor-vehicles, but several automobile manufacturers still use it, and formerly many of the best and most reliable cars were equipped with it. There are many variations in make-and-break appliances, but in all the operation is very similar. A common and simple form is shown in Fig. 8. This apparatus consists of two portions, one part being outside of the cylinder and the other inside; the shaded cuts represent the internal parts and the outline cuts the external parts. The latter consist of a stationary rod, or electrode, of metal (A), which is insulated from the cylinder through which it passes by the mica washers E, E, and to the outer terminal of which one of the coil-wires is attached, the other wire being grounded on the engine. Just below this electrode is a movable rod

(D) with a dog of metal (C) fastened to its outer end and an arm (B) on its inner end. On the arm B and the electrode A are small points of platinum or other hard, heat-resisting material (M). The outer end of C is pierced, and through the hole a rod (H) passes, with a thimble (I) above the arm, and a spring (J) beneath it. Near this is a sliding-rod (L), which works up and down by means of an eccentric on a shaft attached to the motor (O). On the upper end of the rod L is an angular dog (F), which is pivoted and held in position by the little spring K. As the rod L slides up the dog F bears against the spring thimble J and forces the arm C upward

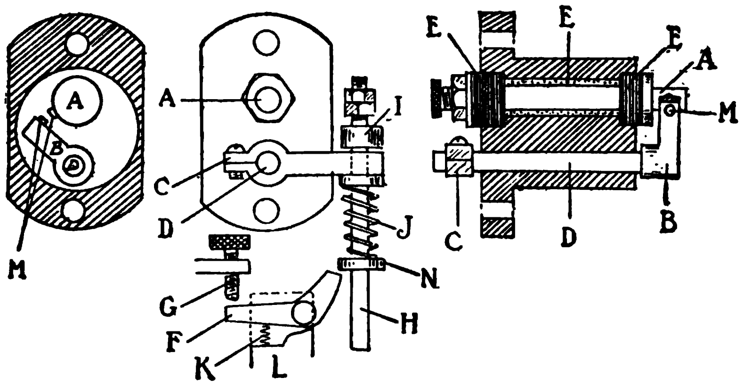


Fig. 8

until the inner end B presses against the electrode A, thus forming an electrical contact within the cylinder. At this point, which corresponds with the upward limit of the piston, the free end of the dog F touches the set-screw G, which causes it to trip from N. As soon as this occurs the spring J forces down the rod H and abruptly snaps the inner arm B from the contact with the electrode, thus producing a sharp spark as the electrical circuit is broken. As the set-screw G may be screwed up or down, the moment

at which the spark is made may be varied by causing the dog F to trip before or after the piston reaches the upward limit of its stroke.

From this explanation and the diagrams you will notice that the moving parts of the make-and-break system are quite numerous, and that the operation is far more complicated than the simple timer and spark-plug method of the jump-spark system. In the latter, however, an induction-coil is required to produce the spark, for the low-tension current of an ordinary battery or coil would not create a spark of sufficient intensity to jump across the points of the spark-plug.

In the make-and-break system, on the other hand, a direct low-tension current from an ordinary spark-coil may be used.

For this reason the wiring of the make-and-break system is far simpler than that of the jump-spark, and the low-tension current is more easily confined than the high tension, and is not so much affected by rain or dampness.

As far as actual efficiency is concerned there is not any real choice between the two methods; but a jump-spark is easier to maintain and requires less adjusting than a make-and-break. In the jump-spark a new spark-plug may be inserted in a few moments, and the trouble, if any occurs, may be easily located, for it must necessarily be in one of the four portions of the system or in the wires. In the make-and-break system, on the other hand, the trouble may lie in any one of a dozen or more places or parts aside from the battery or magneto, the coil, and the wires which are common to both systems.

In the make-and-break the internal moving parts are constantly exposed to great heat, and are liable to burn out, wear, bend, or become coated with soot or carbon. Springs

are unreliable, and a weak spring may put the entire system out of commission—the tripping-screw may become loose, or it may be set too far up or too far down; the mica bushings of the electrode may be broken or dirty and not serve as insulation, or the moving rod bearing the inner arm may stick where it passes through the cylinder, and either fail to break the contact at all or else move so slowly that no spark occurs. Owing to these and other troubles, which often occur on the make-and-break system, most manufacturers of vehicle motors, as well as many builders of marine and stationary motors, have discarded it in favor of the jump-spark system.

As nine-tenths of all motor troubles may be traced to faulty ignition, and as the source of all ignition is the battery or magneto, it is well to become thoroughly familiar with the principle and operation of electrical appliances used in gas-engine-ignition systems.

Chapter V

THE ELECTRICAL EQUIPMENT

Sources of Electricity

THE electricity used for gas-engine ignition is obtained from either batteries or mechanical generators. The batteries may be either dry, wet, or storage batteries, and the generators may be either magnetos or dynamos.

Dry batteries are very convenient, compact, and inexpensive, and a great many motors depend upon them entirely, while nearly all motors are equipped with them as supplementary sources of electricity for starting the engine or for use in an emergency.

Unfortunately, dry batteries soon deteriorate with age; they are ruined by dampness, and have a comparatively short life when used as a regular source of current.

Wet batteries are cumbersome; they are apt to break, and they require frequent refilling. They are used more or less for boat and stationary work, but are not practical for vehicles. Their advantages over the dry batteries are that they are longer lived; they do not deteriorate when idle; and they are not affected by dampness.

Very recently an entirely new type of semi-wet battery has been perfected for motor-ignition purposes. These batteries, known as the "Burn-Boston," are of the same dimensions as the ordinary dry batteries; but, unlike these,

they are long-lived, do not deteriorate with age, and are not affected by dampness, heat, or cold.

Storage batteries are widely used in motor ignition; but these should not be confused with either wet or dry batteries. The latter actually produce electricity, whereas storage batteries merely store or hold electricity generated by a magneto or dynamo.

Some Electrical Terms Explained

Before explaining the principles of batteries or other electrical generators it is well to become familiar with the meaning of certain terms used in electricity as well as certain laws, rules, and principles involved in electricity as applied to gas-engine ignition.

We are accustomed to using numerous erroneous terms in regard to electricity; we speak of it as a *fluid*, and talk about it *passing through a wire.* As a matter of fact, electricity is *not* a fluid, but is a force or power which manifests itself by vibratory impulses which may be either visible or invisible. Instead of passing through a wire electricity travels mainly over the outer surface of the wire. Certain substances are said to be *conductors*, while others are called *non-conductors.* A conductor is any substance or material over which the electricity will travel; or, in other words, anything which will conduct the electrical current. Non-conductors are those substances which prevent the current from passing, and both conductors and non-conductors may be good or poor, so that a poor conductor may almost approach a non-conductor, or a poor non-conductor may allow quite a little electricity to pass over it. Most metals, water, and many minerals are conductors, while wood, glass, mica, leather, rubber, and many other sub-

stances are non-conductors. As water is a very good conductor, wood or other non-conductors when wet will become conductors.

Although electricity travels almost instantaneously from place to place, yet it loses power as it travels from its source, and the poorer the conductor over which it travels the more it decreases in intensity.

As electricity is very different from most forces, and is subject to different laws, certain terms and names have been adopted in connection with it, and these are apt to be very puzzling to one unaccustomed to them. The terms *ohms*, *volts*, *amperes*, *potential*, *high tension*, *low tension*, *magnetic fields*, *induction*, *direct* and *alternating currents*, *spark-gaps*, *insulation*, etc., are in common use, but very few people really understand what they mean.

For the sake of explanation in simple language we can compare electricity to a stream of water flowing through a pipe, although, as already stated, it is not a fluid, and does *not* travel *through* the conductor.

We all know that a liquid flowing through a pipe is said to be under a certain *pressure* which causes it to move, this pressure being caused by a difference in the level between the source and the outlet, or else being produced by some artificial or mechanical means such as a pump.

In a similar manner an electrical current has pressure caused by a difference in what is known as the *potential* between the source and the outlet. This pressure in electricity is called *voltage*.

Thus the term *volt* is the unit of pressure of electricity, just as the term *pound* is the unit of pressure used in measuring the force of water. If you remember that the voltage of an electrical current is practically equivalent to the pressure

of a current of water, you will never have any difficulty in understanding just what the term *voltage* means.

A stream of water passing any given point in a certain length of time has a certain *rate of flow* which is expressed by *gallons per minute*. In a similar way the current of electricity has a rate of flow which is measured by a unit called an *ampere*, which represents *quantity*, just as the quantity of water passing through a pipe is reckoned by gallons. As the quantity of water flowing through a pipe of a certain size is dependent upon the pressure which forces it along, so the number of amperes of electricity which will flow over a certain sized conductor is dependent upon the voltage.

The pipe which conducts the water presents a certain amount of friction which retards the flow of water, and the longer the pipe the more the friction increases. So also an electrical conductor, no matter how good it may be, presents a certain amount of friction to the electrical current, and the smaller and longer the wire, or conductor, the greater will be the *resistance* to the current. Just as the flow of water is retarded by friction, and may be increased by pressure, so the electrical flow, or *amperage*, is reduced by resistance and may be increased by *voltage*. A small water-pipe will not carry so many gallons per minute with the same pressure as a larger one; but if the pressure is increased the same quantity may be forced through the smaller pipe. In the same way a small wire, or a poor conductor, will not transmit as much electricity with the same voltage as a larger wire, or a better conductor, but by increasing the voltage the flow, or amperage, may be increased. Wherever you use electrical apparatus this fact should be borne in mind, and you should use as large wires as possible, and should employ those which are of the best conducting

material. As the current travels mainly over the external surface of the wire, many-stranded wires are preferable to single wires, for this construction admits of the greatest area of surface with the same diameter.

The resistance to water is called *friction*, and, as above explained, this friction depends upon the size, length, and shape of the pipe, as well as whether it is straight, crooked, smooth, or rough. In electricity the resistance, or friction, is measured by a unit known as an *ohm*, and is dependent upon the diameter, length, and material of the conductor, or wires. Every electrical generator, no matter whether it is a battery or a magneto, produces a certain voltage, and consequently can produce a certain amperage. If the amperage drawn from a battery is large, a greater voltage will be required to furnish it, and consequently the more rapidly will the battery be exhausted. The magneto, on the other hand, does not become exhausted, as it produces the current by mechanical means, and for this reason magnetos are more reliable and more economical than batteries as a source of current for gas-engine ignition.

Electrical currents are divided into two general classes called *low tension* and *high tension*, and *direct* and *alternating* currents. A low-tension current may be transformed to a high-tension current, and a direct current to an alternating current, or *vice versa*. Some gas engines employ a low-tension direct current for the make-and-break system, while others employ a high-tension alternating current for the jump-spark system. Batteries produce a low-tension direct current, whereas magnetos and other mechanical generators may produce either a low-tension direct current or a high-tension alternating current, according to their construction.

A *direct current* is a current which flows from the generator

in a steady "stream," and may be indicated diagrammatically by a straight line (Fig. 1). An alternating current, on the other hand, flows first in one direction and then in another, and it may be represented by a curved line, as in Fig. 2. Such a current starts at zero, rises to its highest voltage, and gradually dies away to zero, and then passes in the

Fig. 1

Fig. 2

opposite direction to its maximum and again dies down. This operation is repeated over and over again so rapidly that it appears like a steady flow of current.

Low-tension direct currents are readily controlled, and are prevented from passing where they are not wanted by a very little insulation, or a thin non-conductor. High-tension alternating currents, on the other hand, are difficult to control, and must be confined to their proper place by heavy insulation, or non-conductors.

How Batteries and Magnetos Produce Electricity

All batteries, whether wet, dry, or semi-dry, are composed of some compound known as the *electrolytic* and two kinds of metal, or a metal and carbon. The electrolytic, composed of certain chemicals, acts upon the two metals, or the metal and carbon, and produces an electrical current which is manifested at the poles, or terminals, of the metal plates.

In Fig. 3 an ordinary dry battery is shown in section. In this A represents the outer cylinder of zinc and B the inner core of carbon, while C is the filling of chemicals. One pole is attached to A, while the other is attached to B. As a certain amount of the chemicals and a certain amount of the zinc is consumed in producing the electricity, you will readily understand that the life or usefulness of such a battery depends upon the amount of electricity that is drawn from it. If only a little current is drawn intermittently the battery will last a long time, but if a large amount is drawn from it constantly it will produce electricity for only a very short period.

Such a cell or battery produces only about 1-1/2 volts; but if a number of such batteries are connected in a certain manner, which will be explained later, the voltage may be increased and the batteries will last longer, as the amperes used will be drawn from every cell proportionately instead of from one cell alone. It is as if you were drawing a large pipe full of water from a single small pond; in that case the pond would soon be drawn off, but if there were a number of small ponds, and all were connected, the same amount of water could be drawn for a much longer time.

Moreover, batteries will *recuperate*, or accumulate, electricity to a certain extent even after being apparently exhausted, just as the pond, after being drained off, will again fill up from springs and brooks if the flow of water through the pipe is stopped. Unlike the pond, however, the batteries will not "fill up" with electricity over and over again, but will gradually be exhausted until useless.

Magnetos and Dynamos

Mechanical generators of electricity are commonly called *magnetos* and *dynamos*, and as both of these types of

instruments depend upon the phenomena known as *magnetic induction* for their operation, a few words in regard to this mysterious power will make an explanation clearer.

A famous English chemist, Michael Faraday, discovered in 1831 that if a magnet is suddenly inserted in a coil of wire a current of electricity is produced in the coil. While the magnet remains stationary no current is generated; but as soon as it is moved it again generates the current. This mysterious and little-understood current is known as an *induced current.* and the real force which

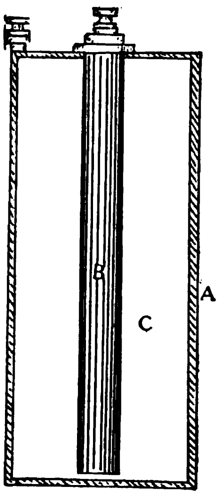


Fig. 3

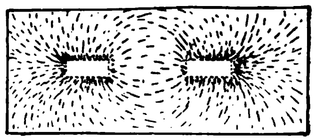


Fig. 4

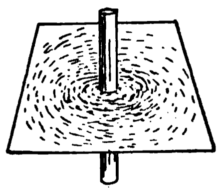


Fig. 5

produces it is the mechanical energy expended in moving the magnet. This mechanical energy is transformed to electrical energy by the medium of the magnet's *magnetic field.* This magnetic field is a remarkable condition existing in space around every magnet. While little understood, the magnetic field may be easily made visible by placing a sheet of glass over a magnet and sprinkling this with iron

filings, whereupon the filings will settle in curved lines as shown in Fig. 4. This arrangement is known as a *magnetic phantom.* A coil of wire carrying an electrical current also possesses a magnetic field, which may be shown by thrusting a wire through a piece of cardboard and sprinkling with filings, as shown in Fig. 5. Both of these forms of magnetic fields are utilized in the electrical equipments of gas engines, and therefore you should be familiar with their principles and peculiarities in order to thoroughly understand the electrical instruments connected with a motor.

The magneto is widely used in generating electricity for gas engines, and, while apparently complicated, this instrument is really very simple. In Fig. 6 a simple form of magneto is shown diagrammatically. In this cut A and B are the soft-iron magnets between the poles of which a magnetic field exists. In this field is a revolving armature (C) wound with wire. While at rest no current exists in this wire, but as soon as the armature revolves it moves through the magnetic field and produces a current in the wire. As the rotating armature produces currents which flow in opposite directions, means must be provided for gathering the current and causing it to flow in one direction. This is accomplished by a segmented copper piece called the *commutator* (E), and bits of metal or carbon known as *brushes* (D, D), which bear upon the commutator. By this arrangement the current flows in one direction along the outside wires where it is to be used.

The dynamo (Fig. 7) is a similar machine in which the magnets (A, B) are electromagnets, or, in other words, soft-iron cores wound with a coil of wire (S, S), which carries a small current known as a *shunt current,* and which is really a small part of the current generated by the dynamo itself. Between the poles of these magnets is the magnetic

field, and within this field the armature C rotates exactly as in the magneto, and the current induced is gathered up and made to flow in one direction by brushes (D, D) and the commutator (E) as already described.

The strength of the current produced by either a magneto

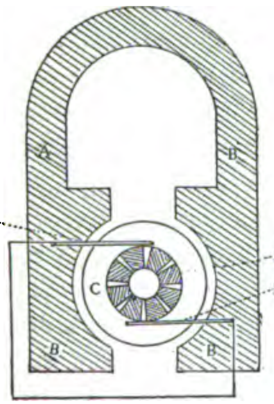


Fig. 6

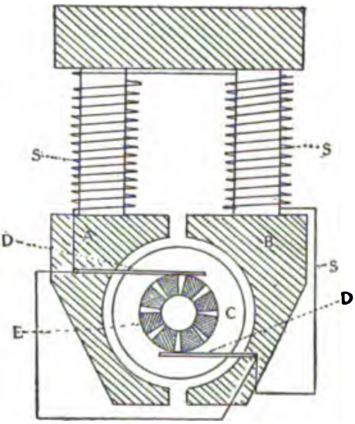


Fig. 7

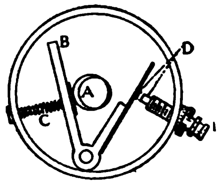


Fig. 9

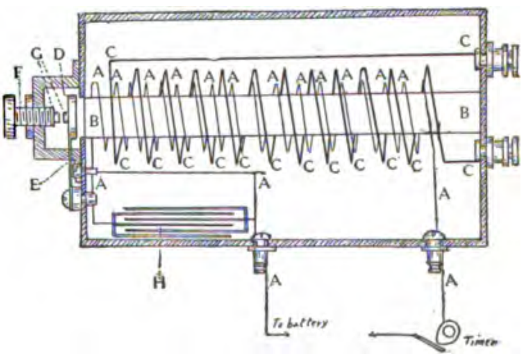


Fig. 8

or a dynamo depends upon the size of the wire used in winding, the strength of the magnets, the number of turns of wire on the armature, and the speed at which the latter

revolves. For this reason the current increases very rapidly with an increase in speed, and this is particularly true of the dynamo. To overcome this tendency, which would soon burn out the wires, a governor of some sort is used to maintain a regular and correct speed regardless of the engine speed.

Magnetos or dynamos are divided into two general classes, low-tension and high-tension, and the main difference between the two is that the low-tension machines have a single winding, whereas the high-tension magnetos have a secondary winding, through which a current is induced by the magnetic field of the first coil.

In the low-tension machines the current is used exactly as in the case of batteries, and it is passed through a spark-coil in the same way as the battery current is used. Such machines may be used for either make-and-break or jump-spark motors, but for the latter the high-tension magnetos are more commonly used.

High-Tension Magnetos

There are so many kinds of high-tension magnetos on the market that it would require a special volume to describe them all, or even the most distinctive types; but in a general way they may be divided into two or three classes. In the Bosch, Simms, and several other makes there is a device known as a *breaker*, which makes and breaks the connections of the secondary winding automatically, and thus causes a powerful current to flow through at the proper time and produce a spark at the spark-plugs. With this type of magneto no spark-coil is required, for the magneto itself acts as a generator and coil. The Holley, Splitdorf, Eiseman, and other machines are a sort of combination of low and high tension magnetos, for the

current generated is passed through a separate coil which carries the breaker, and hence to the spark-plugs. Other machines, such as the Remy, have the windings stationary, while the inductors revolve and the current passes through a coil destitute of a breaker and then to the spark-plugs.

In each case the magneto is equipped with brushes of some sort for distributing the electricity to the proper plugs on the engine in their regular order of firing. Some makes employ a segmented copper commutator, as described, which passes over brushes connected to the wires to the plugs, while others have a single brush and a mechanical distributer. As a rule each magneto requires special adjustments and care, and, as each manufacturer furnishes very minute and detailed directions for the care, use, and adjustment of the instruments, it is better to follow and study these than to attempt to master all the types in use, unless you expect to make a special study of the subject.

Spark-Coils

As the current from a battery or low-tension generator is too weak to produce a spark which is hot enough to ignite gas, an appliance known as a *spark-coil* is used to increase the intensity of the current.

It is a remarkable fact that a current of electricity, when passed through a coil of wire around a soft-iron core, will become greatly intensified, and the larger the coil and the more turns of wire there are the greater will be the size of the spark produced. A coil of wire of this sort is known as a *spark-coil*, and produces a direct current like that of the battery itself. These simple single coils are used on all make-and-break systems; but for the jump-spark system a different type of coil, known as the *induction-coil*, is used.

This kind of a coil depends for its action upon the principle of induction, as already described, and consists of two separate coils of wire around a central iron core. One of these coils is of fairly good-sized wire, and is connected with the battery or other source of current, while the other coil is of extremely fine wire and is not connected with the other at all. This secondary winding is the one which produces the spark, and the powerful current which it carries is an induced current caused by the primary winding and magnet with their magnetic field.

In Fig. 8 an induction-coil is represented in section. In this A represents the primary winding around the core B, with the secondary winding at C. This second coil is composed of thousands of turns of wire carefully insulated, and each turn separated from the next by waxed paper. The more numerous the turns of wire in this coil the more powerful will be the induced current. If the secondary coil has fifty times as many turns of wire as the primary coil the voltage induced will be fifty times as great as the original current.

As I have already explained, currents are only induced by a magnetic field when the field is changing, or the wires passing through it are moving, and therefore to produce an induced current in the secondary coil some device must be provided for turning off and on the primary current in order to magnetize and demagnetize the core B, and thus change the magnetic field. The device usually employed for this purpose is known as an *interrupter*, or *vibrator* (D). This consists of a flat spring (E), which presses against an adjustable screw (F), with both the spring and screw provided with platinum points, or contacts (G). This spring is placed directly over the end of the core B, and as soon as the current passes around the core through the primary

winding the core becomes an electromagnet, which draws down the spring from its contact with the screw F, thus breaking, or interrupting, the current. As soon as the current is thus broken the core loses its magnetic properties, the spring flies back against the contact on the screw F, the current again surges through the primary coil, and the operation is repeated. In this way the primary current is very rapidly broken and made, and a high-tension interrupted current is induced in the secondary coil. If the two terminals of this secondary winding C are held near together as the current is passing through the coil a brilliant spark will leap across from one wire to the other. Although this spark appears to the human eye as a single spark, yet in reality it is made up of a great number of sparks surging back and forth between the points so rapidly that the eye cannot follow them.

Another important part of the induction-coil is the *condenser*, although as this is generally hidden in the coil-box out of sight, many people are not aware of its presence. The condenser consists of a number of sheets of tin-foil separated by waxed paper, and connected with the terminals of the primary coil as shown at H in the illustration. This device prevents the spark from occurring at the platinum points, and adds to the intensity of the secondary current as well. The general arrangement of the batteries, timer, and other connections of the coil are shown in the diagram, and, as coils are delicate instruments, you should not attempt to take them apart or investigate their internal construction.

The coil described is used only with direct low-tension currents, and where high-tension magnetos are employed no coil is required. Many makes of magnetos, however, employ a coil, and in some of these there is no vibrator or interrupter. The necessity of the vibrator is done away with

by placing a mechanical breaker, or interrupter, in the magneto and passing the current through this. Such a device is shown in Fig. 9, which represents the breaker of the Remy magneto. Here the cam A, attached to the magneto-shaft, presses against the bar B at each revolution, and this alternately makes and breaks the contact of the spring C with the platinum point D, and allows the current to rush through the wires to the coil, which is composed of a core and two windings without the vibrator. By this method a single spark of great intensity is produced, and the delicate, trembling vibrator is eliminated, the breaker taking the place of both this and the ordinary timer on the motor.

Still other systems employ a vibrating-coil for the batteries for starting, and a high-tension magneto without a coil for igniting the charge of gas after the motor is running.

Spark-Coils and Wiring

Both ordinary make-and-break coils and jump-spark or induction-coils are made in a variety of forms. The commonest type of coil in use is the "box-coil" (Fig. 10). In this style of coil the true coil, condenser, etc., are inclosed in a plain wooden case, with the various terminals or connections projecting, and, in the case of a jump-spark coil, with the vibrator also on the outside of the box. For vehicle use the style of coil known as a "dash-coil" (Fig. 11) is usually installed. The dash-coil is practically nothing but a box-coil with a finished case or covering with a hinged top and attachments for fastening it to the dash of an automobile. Many box-coils, and practically all dash-coils, are now made in so-called "unit systems." That is, the coil proper, with its vibrator and connections, is fitted within an outer case, from which it may be readily removed

and another coil substituted in case of trouble. On motor-boats, where coils are exposed to spray, dampness, and other severe weather conditions, the ordinary wooden coils are liable to split, warp, or become short-circuited, and special forms of coils have been designed to overcome these troubles. Make-and-break coils for marine use are often inclosed in a

Fig. 10

Fig. 11

Fig. 13

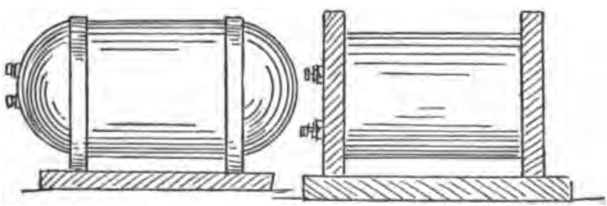


Fig. 12

hermetically sealed metal case (Fig. 12), and marine jump-spark coils are also made in the form of "plug-coils" (Fig. 13). The plug-coil consists of a small, powerful coil and

vibrator within a waterproof cylindrical case, with the lower end terminating in a spark-plug. The plug screws directly into the engine cylinder, like an ordinary plug, and all the high-tension wire is in this way avoided. Plug-coils are not only waterproof, but, as the resistance to the current is decreased owing to the absence of a secondary wire, a much hotter spark is obtained.

No matter which form of coil is employed, there are a certain number of wires that must be used, and a certain arrangement which must be followed, except when high-tension wires are entirely eliminated, as in the plug-coil described.

Simple Wiring

To many a motor-user the question of wiring appears very serious and complex, and it must be admitted that the multitude of wires which cross and recross, run here and there, and begin and end in out-of-the-way places on some of the larger automobiles, really present a formidable problem, especially if the number of wires used for ignition are increased by the addition of wires connected with lighting, self-starting, and other electrical appliances of the modern motor-vehicle.

Nevertheless, if you once learn just why the wires are put in certain places, the use of each, and the proper methods of connecting and protecting them, you will find that any wiring system is readily mastered. A single-cylinder motor is very simple in its wiring, but a four or six cylinder engine appears complicated, and yet the multiple-cylindered machine is merely the single-cylindered system multiplied by the number of cylinders, and by taking each cylinder separately any amateur can learn how to wire or rewire any motor.

In all wiring systems the object is to lead the primary wires in such a way that the electricity from the batteries or magneto will travel from its source around through the switch, timer, and coil back to the source of its origin. In Fig. 14 this is illustrated in the diagram. From the batteries the wire runs from one terminal (A) to the switch, and hence to the timer, then to the coil, and from the coil back to the other terminal of the batteries at B. In order to save wire and additional connections, the frame or iron work of the motor is used as illustrated in Fig. 15. In this diagram the wire from the switch runs to some convenient spot on the motor, usually a screw or nut, and the timer being attached to the motor also, it is just as well connected to the wire as if the wire actually ran directly from the switch to the timer itself. The wire leading from the switch or battery to the engine is known as the *ground-wire*, and where both batteries and a magneto are used there are two ground-wires in many systems.

In wiring a make-and-break motor the current from the batteries is made to flow through the spark-coil before reaching the motor, and in this system one wire leads to the connection provided on the igniter, or to a ground connection, and one of the coil wires leads from the igniter-plug terminal, as shown in Fig. 16. If a magneto is used to operate a make-and-break motor in addition to the batteries for starting it, it is merely connected to the ground terminal with one wire, and with one of the switch contacts with another wire, as shown in Fig. 17. By this arrangement the current from the batteries may be cut out and the current from the magneto turned on by merely moving the handle of the switch from one side to the other. When a jump-spark engine is wired the wires are run from the batteries to the switch, to the ground, and from the timer to

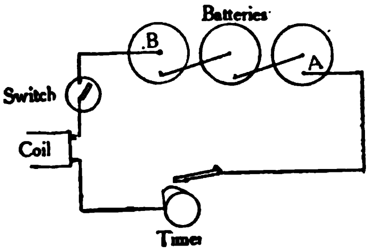


Fig. 14

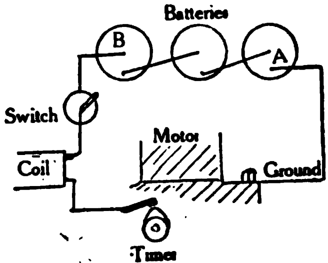


Fig. 15

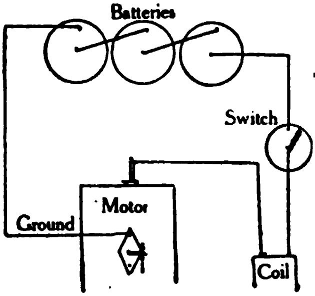


Fig. 16

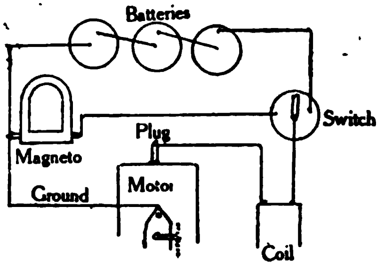


Fig. 17

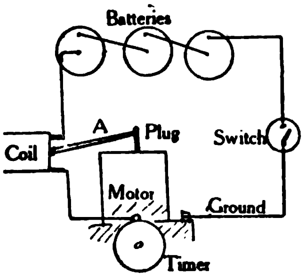


Fig. 18

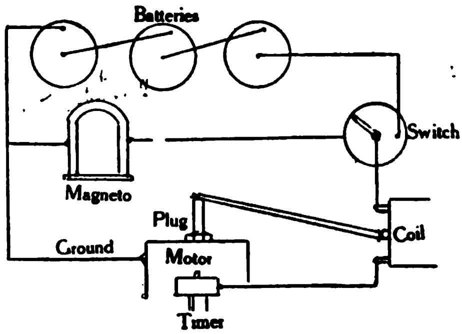


Fig. 19

the coil, and hence back to the battery, as shown in Fig. 18. In this style of coil, however, the powerful secondary current passes to the spark-plug through a special, carefully insulated wire, which is led straight from the secondary ter-

minal on the coil to the top of the spark-plug (Fig. 18, A). Where a magneto is used in addition to batteries on a jump-spark motor one wire is led to the switch, and the other to the coil, exactly as in the case of the make-and-break magneto (Fig. 19). When a plug-coil is used the wire system is practically the same, but it is simplified by the absence of the secondary wire (Fig. 20). All the above directions and illustrations relate to single-cylinder engines; but it is just

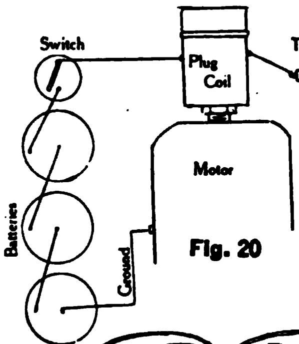


Fig. 20

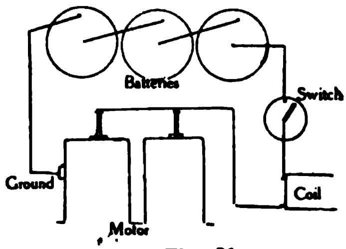


Fig. 21

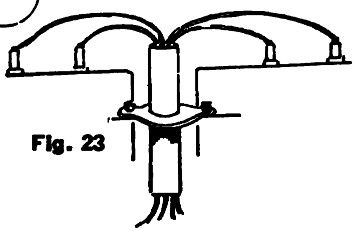


Fig. 23

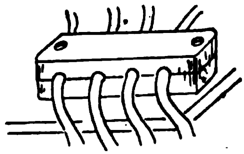


Fig. 24

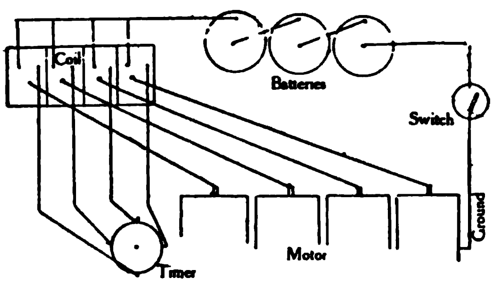


Fig. 22

as easy to wire a two, three, or four cylinder motor if we understand the principle. In Fig. 21 a two-cylinder make-and-break motor wire system is shown, and in Fig. 22 a four-cylinder jump-spark system, and by studying these diagrams you will at once see that the wires are really just as simple as in the single-cylinder motors.

In wiring any motor a great deal of care must be used to see that the wires are protected, or "insulated," so they will not "leak" electricity and short-circuit, and all connections should be made tight so they will not shake loose. A great many motor troubles may be traced to loose wires and poor insulation, for a loose connection may allow the current to pass freely when the motor is at rest, and yet interrupt the current and cause the engine to stop just as soon as it begins to run and vibrates and shakes. In the same way a broken wire, or a spot where the insulation is rubbed off may not show at all when the motor is not operating, but it may either stop the current or allow it to run out through the break as soon as the engine starts up and the injured parts rub against some other object. Ninety per cent. of motor troubles are electrical, so that you should use every effort to see that the electrical system and wiring is as near perfect as possible.

Where wires pass over or near any metal they should be protected by fiber or rubber tubes (Fig. 23), or should be clamped together and supported firmly by wooden or fiber clips, as shown in Fig. 24. In the case of multiple-cylindered engines, where the high-tension wires run for long distances over the motors, it is customary to lead the wires through fiber, rubber, or metal tubes clamped to the motor, as shown in Fig. 25.

Wherever a wire must be fastened to woodwork it should be held in place by a bit of leather or rubber (Fig. 26), or a

piece of leather or some similar substance should be placed under a staple (Fig. 27) before tacking it in place. Always run the wires where they can be easily inspected. You never know when you will have to follow up a wire to find a break, and if the wires are run under seats, inside moldings, and in all sorts of out-of-the-way and hidden spots, you will spend lots of time and trouble finding a break, to say nothing of the damage you may cause by having to rip

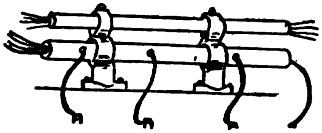


Fig. 25

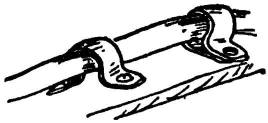


Fig. 26

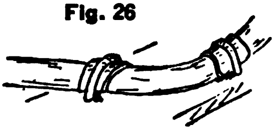


Fig. 27

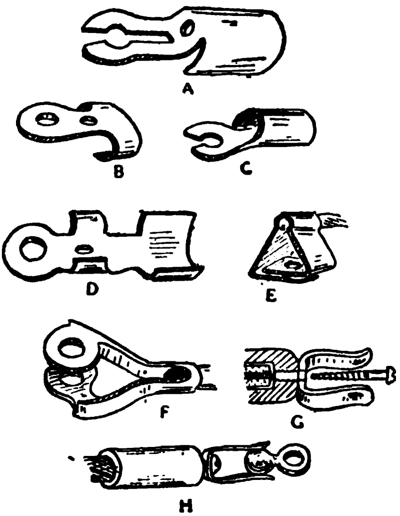


Fig. 28

away woodwork to reach the wires. The author once had to tear the entire panel-work out of the cabin of a power yacht in order to find a tiny spot on a wire where the insulation had been eaten away by a hungry cockroach. As the boat was disabled in a heavy sea a long distance from port, no time could be wasted in removing the handsome woodwork carefully, and an ax and crowbar were used. When the slight repair was completed and the boat again started on

her trip, the cabin was a perfect wreck, and to replace the smashed woodwork cost ten times what it would have cost to have installed the wires properly in the first place.

There are a great many forms of connectors for fastening wires to battery, coil, and other terminals, and, while some of these are better than others, yet the simplest and easiest to connect are the best. Some forms of these are shown in Fig. 28. Such forms as A, B, C are soldered to the wire, while D, E, F are merely clamped in place, and G, H are attached to the wire by screws.

If no regular connector is at hand, you can make a very satisfactory connection by merely twisting the wire around the binding-post and screwing down the nut thereon. A still better way is to form a little eye in the wire, solder it together, and use this as a terminal. Whenever you solder an electrical wire you should use resin, and not soldering-fluids, and after the terminal is formed the end of the insulation should be wrapped with adhesive tape to prevent it from fraying out. Where the ends of two wires are joined they should be firmly twisted and soldered together and wrapped with tape, and, in fact, wherever a wire is exposed or is liable to chafe the tape should be used.

There is no economy in using cheap or poor wire. Good wire is expensive, but it lasts longer and saves many times the difference in price in the batteries saved. Grease, water, oil, and gasoline will destroy and soften rubber insulation on wires, and the poorer the wire the quicker it will be destroyed. Make your wires as short as possible, keep them from grease, oil, and water, run the wires straight, and keep each group separate as far as possible. If the wires must be led out of sight under or through partitions or any other spaces where they cannot be readily followed, it is a good plan to mark each wire with a bit of colored twine or cloth. A still

better plan is to use wires of different colors, and by doing this you can readily trace any wire you wish. *Never* lead a secondary and a primary wire through the same tube or insulator, but keep them separated as far as possible. Even when your wires are perfectly insulated, and at a distance from metal or other wires, you may often find a leak by watching them in the dark. You will often be surprised to see a perfect stream of small blue sparks running from a secondary wire to the nearest metal or to another wire. This is particularly true of boat wires, for wet wood is just about as good a conductor as metal, and wires in a boat are always damp, even if under cover. Whenever you detect these blue sparks in the darkness, support the leaking wire, keep it from any other object, and if possible inclose it in a fiber or rubber tube. If you take precautions to have your wiring perfect, your wires of the best quality, your connections tight, and your high-tension wires well insulated, you will have eliminated the majority of your motor troubles.

Part II

MOTOR ANATOMY

Chapter VI

SINGLE AND MULTIPLE CYLINDER MOTORS

MODERN gasoline engines are made in various numbers of cylinders from one to eight or even twelve. Although a motor with several cylinders may appear far more complicated than a motor with only one cylinder, yet it is not in reality, for a multiple-cylinder motor is merely several single cylinders, with their various attachments, fastened to one shaft.

Of course, there are twice as many parts in a two-cylinder engine as in a single-cylinder machine and three times as many in a six as in a two-cylinder motor, but if you are familiar with the purpose and action of each part of a single-cylinder engine you will understand a multiple-cylinder motor.

In the early days of gas-engine construction the tendency was to produce single-cylinder machines, and when more power was required to make the one-cylinder larger. It was soon discovered, however, that two or more smaller cylinders would give greater power than one large cylinder and were far easier and cheaper to build. Moreover, by adding to the number of cylinders the engines operated more steadily, with less vibration and jar, they consumed less fuel, were lighter in weight, and occupied less space.

To-day, therefore, practically all motors of any size are of the multiple-cylinder type. Marine engines are usually

single-cylinder in the small and medium sizes, and stationary motors of twelve or fifteen horse-power or even more are frequently made with one cylinder, but with the exception of motorcycles practically all modern motor-vehicles use two, three, four, or six cylinder engines, while aeroplanes have motors of from two to twenty cylinders.

The cylinder of a motor is, in a way, its most important part, and yet it is very simple. A cylinder is really nothing more than a tube, open at one end, within which the piston slides back and forth, and provided with proper openings for the inlet and egress of the gases. Simple as is its construction, yet a well-made motor cylinder is a beautiful piece of work. The cylinders are first cast of fine-grain cast iron or semi-steel and are then bored and machined inside until as smooth as glass. As the exploding gas must be prevented from escaping between the walls of the cylinder and the piston, very accurate fitting is required, and the diameter of the cylinder is usually kept within a variation of two one-thousandths of an inch. This is accomplished by means of *limit-gages*. One of these is one one-thousandth of an inch larger than the cylinder-bore should be, and the other is one one-thousandth of an inch smaller than the desired diameter If the large one can be inserted in the cylinder it is too large, and if the small one cannot be inserted the cylinder is considered too small.

Cylinders are of various forms and are made in various ways. Large single-cylinder motors usually have cylinders with a removable top or head held to the cylinder proper by studs or bolts (Fig. 1). This form is cheap to build, it gives easy access to the piston and inside of cylinder, and in the case of four-stroke motors it enables the valves to be easily reached. Such cylinders are used to a large extent in marine and stationary work, and a number of aeroplane and

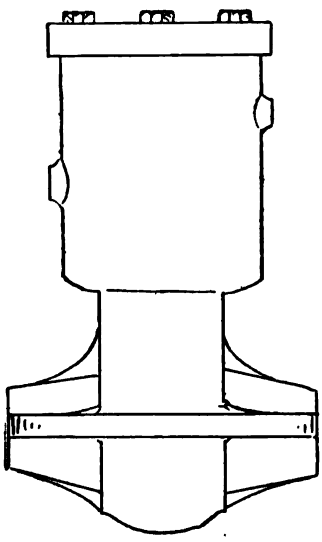


Fig. 1

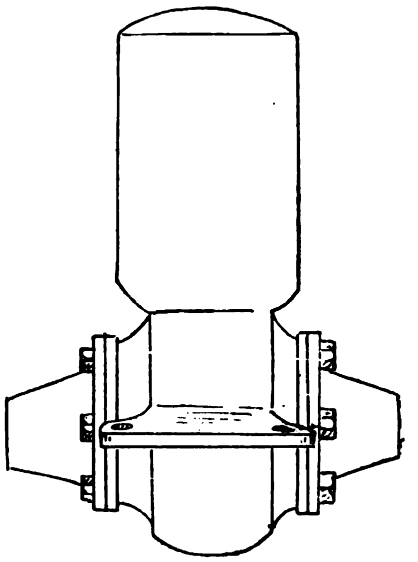


Fig. 2

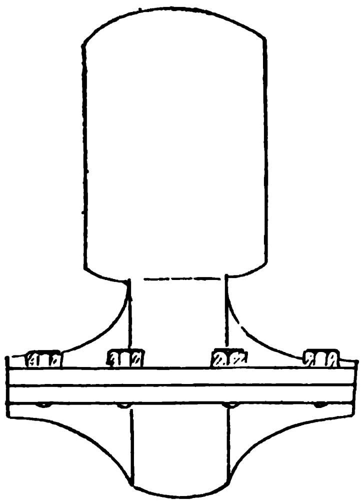


Fig. 3

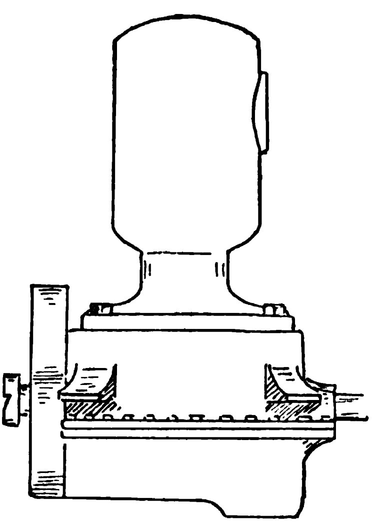


Fig. 4

SINGLE AND MULTIPLE CYLINDER MOTORS

several automobile motors are constructed with separate heads.

Many single-cylinder motors and some multiple-cylinder two-cycle motors are built with cylinders with solid tops and with the ends of the crank-case removable (Fig. 2), but the majority of modern motors are made with solid-head cylinders and split base. The base may be small and fitted closely to the shaft in the case of two-cycle motors (Fig. 3), or it may be large, roomy, and box-like, with the cylinders bolted to the top (Fig. 4), when of the four-cycle type.

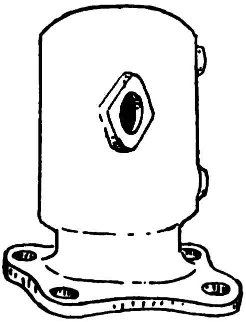


Fig. 5

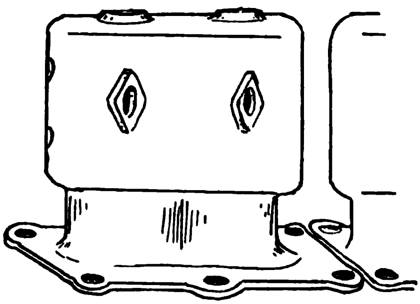


Fig. 6

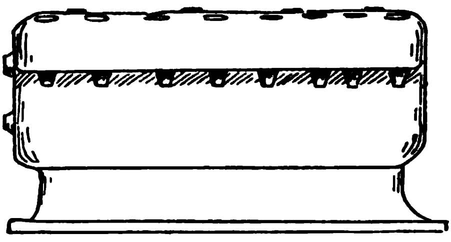


Fig. 7

Gas-engine cylinders may be made separately and bolted to a common crank-case (Fig. 5) or cast in pairs (Fig. 6), or all four or more cylinders may be cast *en bloc*, as shown in Fig. 7. The latter system is now widely used, but it has

many disadvantages. Builders and designers of *en bloc* cylinders claim that such cylinders never get out of line, that expansion and contraction by heat is uniform, that machine work can be done more accurately, and that the whole system is far ahead of separate cylinders. On the other hand, if the wall of one cylinder becomes cracked or injured, a single valve-chamber broken or worn, or, in fact, if any serious trouble occurs in one cylinder, the entire four or more are worthless and a new *en bloc* casting must be obtained. Moreover, such *en bloc* cylinders are very heavy, and if an engine requires repairing or overhauling a powerful hoist or several men are required to lift off and replace the cylinders. In the case of motors with separate cylinders, or cylinders in pairs, a single cylinder or a pair may be replaced at comparatively small expense, and one man or a good strong boy can easily lift off and replace cylinders of this sort.

Crank-Cases

Below the cylinders and surrounding the shaft is the *crank case* or *base*. In the case of a two-cycle motor this case is very small—in fact, it is usually just as small as it can possibly be made and permit the crank and connecting-rod to revolve within it (Fig. 8)—and the ends extend over the shaft and fit snugly around the bearings. In four-cycle motors the case is much larger and is usually box-like, with the cylinders fastened to the upper side. Within this big crank-case are the bearings, the cam-shaft, the cams, the oiling system, and the various gears (Fig. 9). Many people cannot understand why there should be such a great difference between the crank-cases of these two types of motors, but it is very simply explained. The two-cycle motor sucks the charge of fuel-gas into the base, and from this space

forces it into the cylinder as explained in Chapter I. For this reason the base must be air-tight, and it must be of a size proportionate to the capacity of the cylinder. If too large there would be little suction when the piston traveled up, and

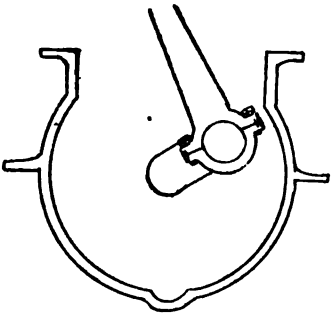


Fig. 8

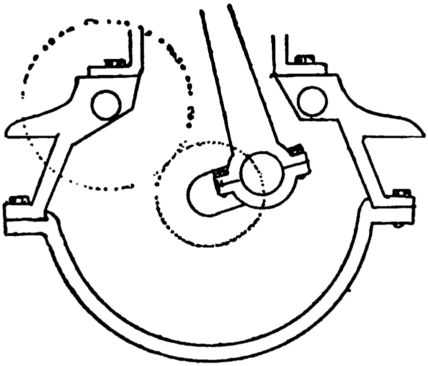


Fig. 9

if the base was filled with fuel there would be too much to force into the cylinder. As the revolving-crank and connecting-rod require a definite amount of space for their movement, the crank-case must be designed so as to give room for the crank and yet not be too large for the fuel charge, and as a rule in order to accomplish this the case has to fit the revolving-crank very closely.

Four-cycle motors, on the other hand, suck in the charge of gas through the upper part of the cylinder, and the base is merely a support for the shaft and a covering for the moving shaft and cranks. Many marine and stationary motors of the four-stroke type have the base entirely open at the sides and the revolving-shaft and moving connecting-rods can be seen in action. Vehicle motors, however, have the crank-case completely inclosed to prevent the oil from being thrown out, and also to protect the moving parts and bearings from dust, dirt, and grit.

Crank-cases may be of iron, steel, bronze, aluminum, or other metals, but they are usually of aluminum in the best four-cycle motors and of cast iron in the two-cycle forms. A crank-case of a motor may seem a very simple affair, but if you break one and wish to purchase a new one you will be surprised at the cost. A comparatively small crank-case for a vehicle motor will cost over one hundred dollars, and as a rule the crank-case costs more than any other one part of the engine. The case has to be very strong and rigid, as it supports the entire motor, it has to be carefully and

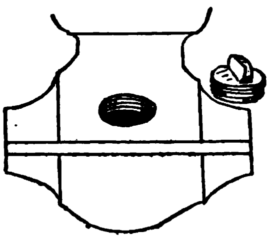


Fig. 10

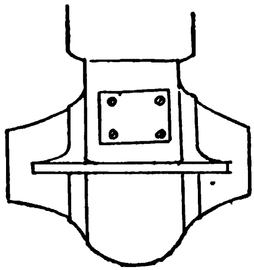


Fig. 11

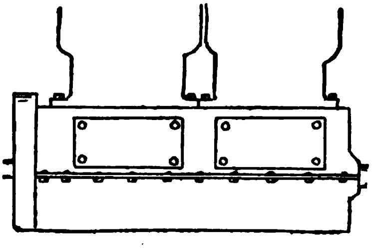


Fig. 12

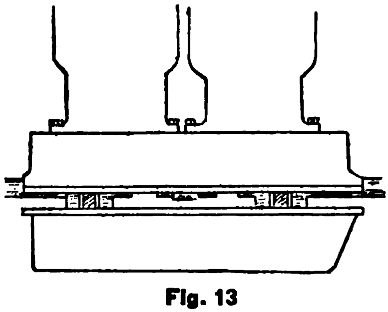


Fig. 13

accurately made, and it requires a great deal of machine work to enable the various parts of the motor to fit properly in place and in perfect alignment. In addition, all the joints are accurately trued up and must be air-tight.

To obviate the necessity of taking off the cylinders to reach the inside of the crank-case, openings with removable plates are usually provided. Two-cycle motors may have merely a large hole fitted with a plug on one side (Fig. 10), or a square plate may be fastened by screws over a large opening (Fig. 11). Four-cycle motors usually have ample plate-covered openings opposite each crank (Fig. 12), and in addition have the lower portion of the crank-case removable (Fig. 13). This is a matter of considerable importance, for it would be very inconvenient to have to tear down the entire motor to tighten a bearing or connecting-rod. Moreover, it is sometimes impossible to tell whether the trouble actually is in a bearing or not, and the motor might be taken down only to find out that the bearings were in perfect condition and all the time and trouble had been wasted. By removing the plates the bearings may be inspected or adjusted, and by taking off the lower half of the case all the internal mechanism of the motor is exposed and accessible (Fig. 14). This shows the appearance of a four-cycle motor after the lower part of the crank-case is removed, as it appears looking up into the case. You will see that the greater part of the case is occupied by the round rod or shaft (A), with the various crank-throws (B) and their bearings (C). Over each crank is a round hole which is the lower end of a cylinder, and some of the cranks extend

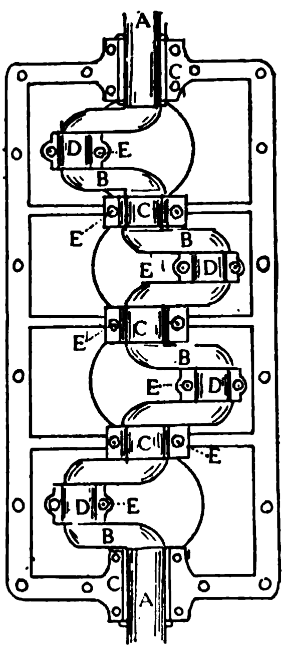


Fig. 14

up into these, while others hang down below the shaft. On each of these is a large bearing forming the lower end of a connecting-rod (D). Each of the bearings (C) is held in position by bolts and nuts (E), and, as these bearings and their construction are extremely important and require a great deal of care, they should be thoroughly understood.

Shafts and Bearings

"Out of sight, out of mind" is an old saying which is very true of the shafts and bearings of motors. Most motor owners or operators never give a thought to the bearings or crank-shafts of their engines until something goes wrong, and then they wonder why it happened and how so much damage was done without any warning. The shaft and bearings take all the strain and explosive force of the motor and transmit all the power to the machinery. The shaft is continually in motion whenever the motor is operating, and until you stop to figure it up you cannot conceive of the enormous number of times that a shaft whirls around in its bearings during a few hours' run. If the motor is operating at the slow speed of five hundred revolutions a minute the shaft turns three hundred thousand times in ten hours and turns, moreover, with the whole weight and resistance of the machine against it. When you stop to think that the shaft and bearings are often untouched or uncared for for month after month and even for year after year is it any wonder that they become worn, cut, bent, or ruined?

Shafts are often made far too small or weak for the motor, in the first place. They should be designed with a great excess of strength and should be forged from the highest grade of chrome, vanadium, or nickel steel, and thoroughly heat-treated and annealed to insure strength and toughness.

They are usually machined to within three one-thousandths of an inch in size, and the bearing surfaces must be ground to a mirror finish. The slightest roughness or unevenness of a bearing surface will result in a cut or scored bearing,

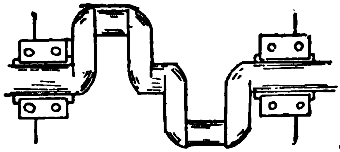


Fig. 15

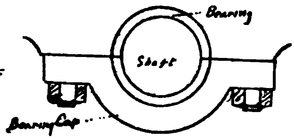


Fig. 18

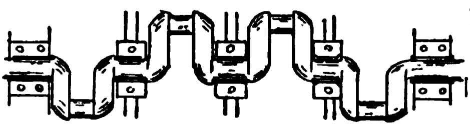


Fig. 16

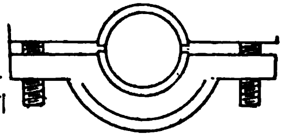


Fig. 19

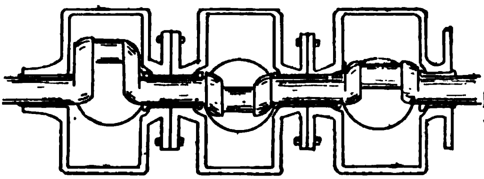


Fig. 17

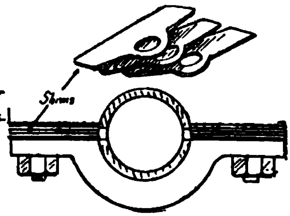


Fig. 20

and this in turn will ruin the shaft. The number and kind of bearings of a shaft depend largely upon the style, size, power, and duty of the motor and upon the individual ideas of the designers. Many motors have bearings far too small or too light or too few in number. A single-cylinder or a two-cylinder motor may get along very well with two end or main bearings to the shaft (Fig. 15), but engines of three, four, or more cylinders should have a bearing between every crank, in addition to the longer main end bearings (Fig. 16). Of course, this applies only to four-cycle motors,

for two-cycle motors have to be air-tight between the cylinders, and to accomplish this a tight bearing is always provided (Fig. 17). As one end of the shaft supports the heavy fly-wheel and the other end supports the gears or other mechanism, it is important that the two end bearings should be larger and stronger than the others. Bearings may be of various substances, such as Babbitt, white bronze, or special alloys, but in every case the object is to provide some metal which possesses great anti-friction qualities, which is softer than the steel of the shaft, and which will wear to a beautiful polished surface. In some very high-grade four-cycle motors the bearings are of the roller or ball-bearing type, and these are almost universally used in aeroplane engines.

As the bearing metal itself is very weak and would not support the shaft, the bearings are made in light, thin pieces and are held against the shaft by cases of strong metal known as *bearing-caps* (Fig. 18). Two-cycle motors usually have the end bearings in a solid one-piece tube or cylinder fitting tightly over the shaft and fastened in the bearing-cover, but four-cycle motors have the bearings in two pieces which are adjustable to take up wear and keep the bearings tight on the shaft.

There are various methods employed for adjusting bearings and holding them in place under the caps. Usually the bearings are made so that they form a circular section when the edges are some distance apart (Fig. 19), and the two halves are kept separated by *shims*, or thin pieces of metal, placed between them (Fig. 20). By removing one or more of these shims the bearings may be adjusted very accurately. The caps are usually held in place by studs or bolts threaded into the upper part of the crank-case, and to prevent these bolts from becoming loose or the nuts from backing off

various forms of lock-nuts, cotter-pins, etc., are employed (Fig. 21). It is very important to have the bearings fit snugly on the shaft and to have the caps securely fastened, for if this is not done the bearings will soon work loose through the jar and vibration and will cut and break. A loose main or connecting-rod bearing will very rapidly destroy or injure the entire motor, for the jar and pound

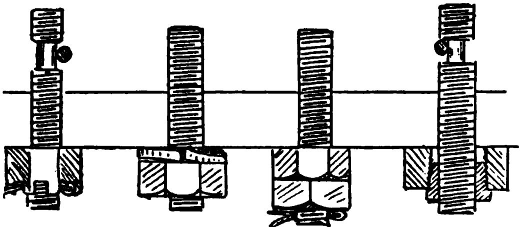


Fig. 21

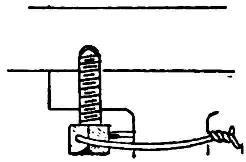


Fig. 24

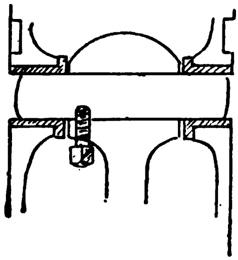


Fig. 22

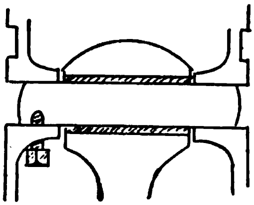


Fig. 23

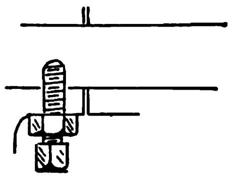


Fig. 25

occasioned by the loose shaft or connecting-rod will shake bolts, nuts, and fastenings loose; the connecting-rod may bend or break, the shaft will bend or twist, and if the motor is operated under such conditions a smashed crank-case, broken cylinders, or a wrecked motor results. As all sorts of troubles may originate in loose bearings, you see how vastly important it is that they should be properly made and designed in the first place and constantly looked after and adjusted by the operator.

The other bearings in the motor are the small piston-

pin bearings, the cam-shaft bearings, and the gear-bearings. As a rule these give very little trouble, for all these smaller bearings are simple bronze bushings, and, as the parts are light and carry but little load, the bearings last a long time. Piston-pin bearings may be either in the piston, with the pin fastened immovably to the connecting-rod (Fig. 22), or the bearing may be in the end of the connecting-rod with the pin fixed in the piston (Fig. 23).

Some makers use one system and some the other, but in either case it is very important that the piston-pin itself should be prevented from moving endwise and thus striking the cylinder walls. To prevent this several methods of fastening the pin in place are in general use. The commonest method is to use a set-screw with a wire passed through a hole in the head of the screw to prevent it from turning out (Fig. 24). Another method is to use a set-screw and lock-nut (Fig. 25). Other designers use a screw in the end of the pin and various other devices.

Some motors have ball or roller bearings throughout, and, while this is not usual in automobile or marine motor construction, in aeroplane motors it is generally adopted. Roller-bearings consist of a cage or retainer within which are a number of cylindrical or conical steel rollers which run either on a cone of hardened steel or upon the shaft itself. Several types of roller-bearings are shown in Fig. 26, while several forms of ball-bearings are illustrated in Fig. 27. Ball-bearings are in very general use. In this type of bearing the rollers are replaced by polished steel balls running against a hard steel cone or upon a steel ring on one side and a cup or ring on the other. The form shown in Fig. 27 A is employed where there is an endwise pressure or *thrust*, and consists of two steel plates, or *races*, on either side of a brass plate, or *cage*, containing the steel balls. Fig. 27 B

shows the construction of an *annular* bearing in which there is little thrust, while Fig. 27 C shows a cup-and-cone bearing used where thrust and weight are combined, as in the case of axles, shafts, etc. The corresponding forms of roller-bearings are shown in Fig. 26, A, B, C, but where roller-bearings are used and there is considerable end-thrust ball-bearings are frequently used in connection with them. Either ball or roller bearings reduce friction to the minimum and have a very long life. They require but little attention

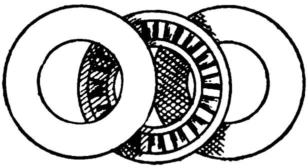


Fig. 26 A

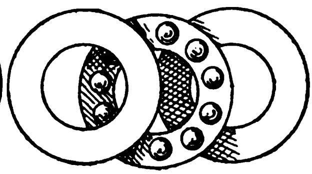


Fig. 27 A

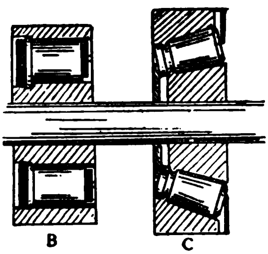


Fig. 26 B

Fig. 27 B

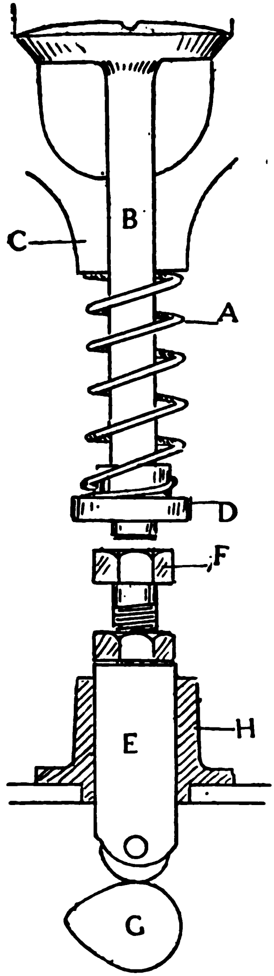
Fig. 27 C

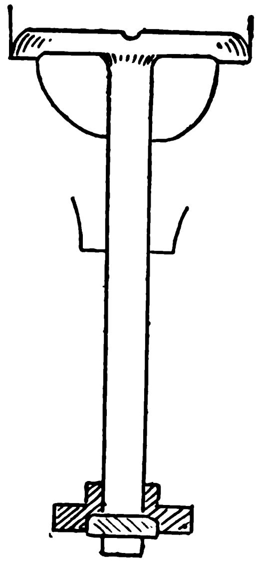
and very little adjustment, and when properly made are the best bearings obtainable. They are exceedingly expensive, and for this reason are only used in very high-grade motors.

Valves

In every four-cycle motor there are two valves to each cylinder, one of which admits the fuel, the other allowing

the burned gas to escape. These are known respectively as the *intake-valve* and *exhaust-valve*. There are many forms of valves in use, but the commonest form, known as the *poppet-valve*, is the simplest; Fig. 28 shows two forms of this type of valve, one with a beveled lower surface resting





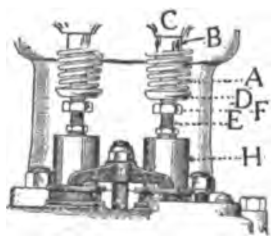


Fig. 28

upon a beveled seat, the other known as a *mushroom-valve*, with a flat lower surface resting upon a flat seat.

The valves are held in position by a stiff spring (Fig. 28, A) placed around the valve-stem (B), and bearing on the valve-stem guide (C) at one end and upon the valve-foot (D) at the other end. To prevent the valve from moving sidewise or from seating unevenly a guide (C) is provided in which the stem slides up and down. The valves are lifted from their seats to admit a charge of gas or to let the burned gas escape by means of rods known as *push-rods* (Fig. 28, E). These push-rods carry an adjustable nut or pin, called a *tappet*, at their upper end (F), and bear upon the cam (G) at the other end and slide up and down in bronze bushings or guides (H). As each valve must open at a certain point in relation to the position and motion of the piston and must remain open for *one stroke*, or *one-half* of a revolution, and must remain closed for the next *three strokes*, or *one and one-half* revolutions of the shaft, the cams must be operated at one-half the engine speed; in other words, the shaft carrying the cams makes but one revolution while the main crank-shaft is making two complete turns. This is accomplished by using gears on the shaft and cam-shaft and having the cam-shaft gear just twice the size of that on the crank-shaft. The gears used may be plain *spur-gears* (Fig. 29), *skew-toothed gears* (Fig. 30), *worm-gears* (Fig. 31), or sprockets and chains (Fig. 32). Some motors have the cam-gear driven direct from the main gear (Fig. 33), while others use an *idler-gear* between the two (Fig. 34). In order to have the valves open and close at just the right point in relation to the piston the cam-shaft and cam-gear must be set in a certain definite position in relation to the shaft-gear. This is known as *valve-timing*, and is a matter of very great importance. While the exact timing of the valves varies a little with

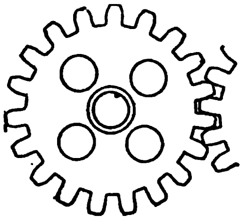


Fig. 29

Fig. 30

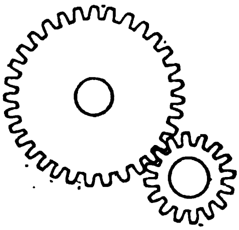


Fig. 33

Fig. 31

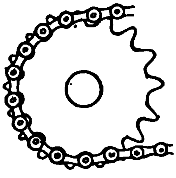


Fig. 32

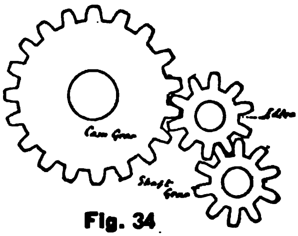


Fig. 34

different motors, yet in a general way the timing of all motors is alike. In Fig. 35 the piston is shown at the beginning of the downward stroke with the cam A just commencing to push up the rod and open the intake-valve A. As the piston continues on its downward stroke the cam gradually pushes the valve higher and higher until the piston nears the center of its stroke and begins to travel up the cylinder. At this point (Fig. 36) the cam commences to move away from the push-rod and allows the valve to close upon its seat as the piston commences its upward travel. The charge in the cylinder which has been drawn in during the downward stroke is now com-

pressed and is fired at the time the piston reaches its upward limit. During this upward stroke and the following downward stroke both valves remain closed, for the cam-shaft, making but one-half a revolution during the complete turn of the main shaft, does not bring the cams against the push-rods until the next upward stroke has commenced, as shown in Fig. 37. At this point the exhaust-valve cam (B), which is approximately at an angle of ninety degrees from the intake-valve, commences to bear upon the push-rod and to raise the valve from its seat. During the upward stroke of the piston, or one-half of this revolution of the crank, the exhaust-cam travels through one-quarter of a revolution, thus allowing the exhaust-valve to seat just as the piston completes its stroke, whereupon the intake-valve again commences to open. By studying these diagrams you will see that the intake-valve opens at practically the upward limit, or *dead-center* of the fly-wheel, and closes at the lower limit or downward dead-center, and that the exhaust-valve opens at the lower limit, or downward dead-center, and closes just before the upward dead-center. In actual practice the valves are designed to open and close a little earlier or later than dead-center to allow for *lag* in the mechanical action and the momentum of the incoming and outgoing gases. As every motor varies slightly in this detail, the makers usually mark the surface of the fly-wheel as a guide to the proper timing of the valves. A fly-wheel with these markings indicated is shown in Fig. 38, and when adjusting a motor the valves should be accurately timed to correspond to these marks. Slight deviations from exact timing may be corrected by adjusting the tappets up or down, but if any great alteration is required it must be accomplished by turning the gears and moving their intermeshing teeth either farther ahead or farther back.

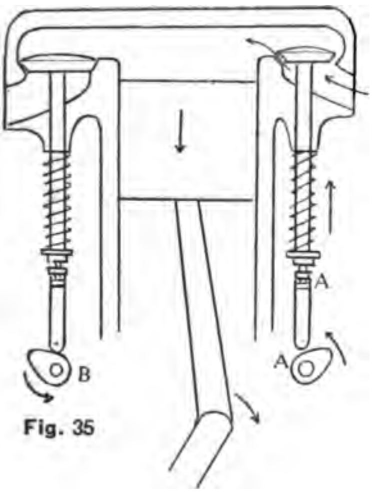
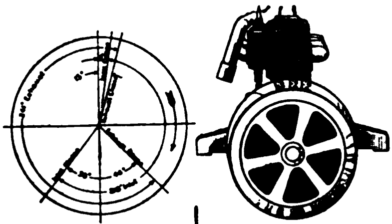


Fig. 35



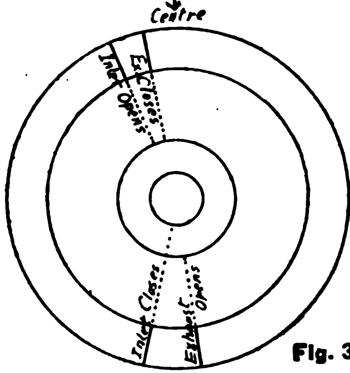


Fig. 38

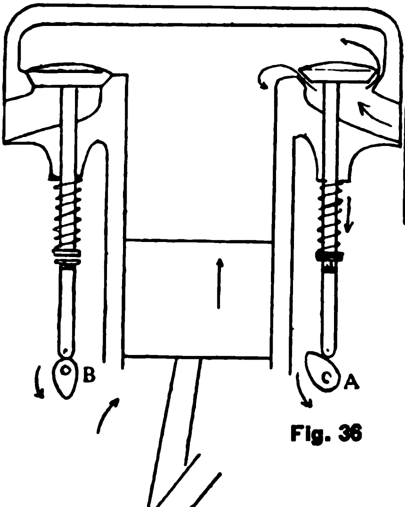


Fig. 36

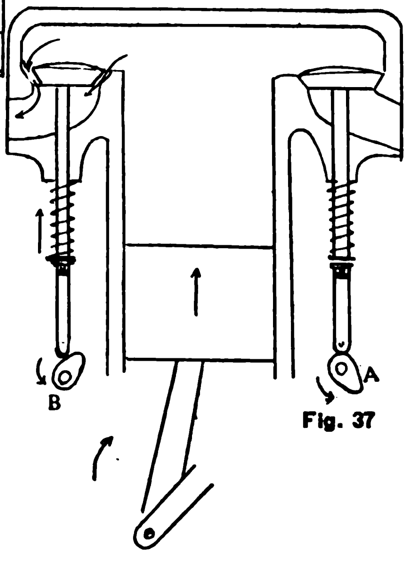


Fig. 37

PISTON AND VALVE POSITION AND TIMING MARKS

Position of Valves

The valves may be placed in several different positions on the cylinders of a motor. They may be on the top of the cylinder itself, in a special chamber on one side, one on one side and the other on the opposite side, or one may be in the side and the other in the top.

When both valves are placed side by side in a valve-chamber on one side of the cylinder the motor is known as an *L-head*. If one valve is on one side and the other one opposite, the motor is a *T-head*, and if the valves are over or on top of the cylinder the motor is an *overhead*-valve engine. These three typical forms are shown in Fig. 39. A great many makers combine two of these forms and place either the intake or exhaust valve in the head of the cylinder and the other valve in a chamber at one side (Fig. 39, D). Each method has advantages and disadvantages, and if properly designed and proportioned there seems to be but little difference in the comparative power and efficiency of the various forms. An overhead valve permits a more direct inlet and outlet to the cylinder, but such valves require more complicated mechanical devices for operating them, such as rocker-arms, extension-rods, etc., as illustrated in Fig. 40, and, moreover, a broken valve-spring or valve-stem or a loose pin or fastening may allow the valve to drop into the cylinder and break the piston or even the cylinder itself. T-head construction requires two sets of cam-gears, two cam-shafts, and a large clumsy and heavy base, and has no particular advantages. L-head motors require but one cam shaft and gear and are very compact, but the valve-chamber interferes more or less with the movement or flow of the gases. A great many motors are made with one valve on the side and one in the cylinder-head,

and this method is very satisfactory. Some designers place the exhaust-valve in the head and the intake in the side, while other designers reverse the arrangement and place the intake-valve in the head. The question of power and reliability is really more dependent upon the diameter and

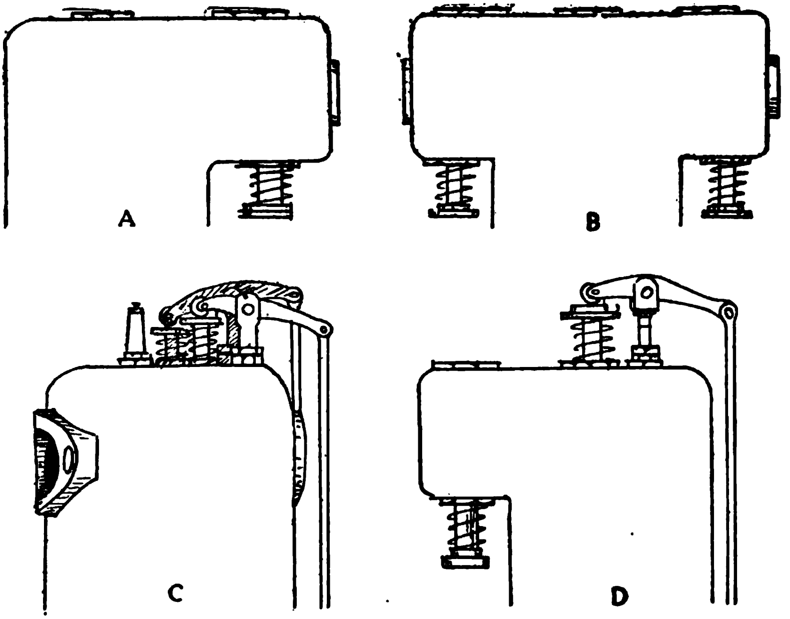


Fig. 39

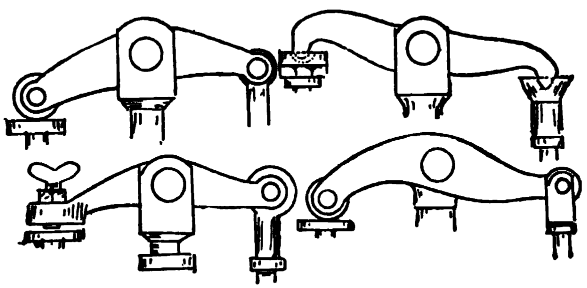


Fig. 40

lift of the valves and the mechanical details of their operation than upon their position in the cylinder, but, all things being equal, overhead valves usually produce more powerful motors than either L-head or T-head arrangements. One great disadvantage of any overhead-valve motor is that such motors are invariably noisy. L-head or T-head motors may have all the valve mechanism inclosed, and there are so few moving parts that with proper adjustment the valves are almost noiseless; but overhead valves cannot be easily inclosed, and there are so many pivots, joints, etc., to the operating devices that as soon as they become slightly worn they clatter and become noisy, even in the best motors.

As the explosive impulse of the gas must occur at a certain time in relation to the position of the valves, the moment at which the spark takes place must be determined and the sparking mechanisms must be arranged to operate in direct relation to the position of the cam shaft and gears.

This is accomplished by connecting the timer or magneto to the cam-shaft or by operating it by a special gear. As the spark in the cylinder occurs on every *fourth stroke* or *second revolution* of the main shaft in four-cycle single-cylinder motors, the timer or magneto must make its contact once in every two revolutions, or, in other words, at *cam-shaft speed.* Hence by connecting the magneto or timer to the cam-shaft the proper speed is obtained, and if a special gear is used this must be either of twice the main-gear size and meshing with it or of cam-gear size and meshing with the latter. While I speak of "twice" the size, this is in a way misleading, for by the use of worm-gears the speed may be increased or reduced without correspondingly altering the size of the gears.

Two and four cylinder four-cycle motors have the magneto driven at crank-shaft speed, three-cylinder engines at

three-fourth crank-speed, and six-cylinder motors at one and one-half times crank-shaft speed.

Two-cycle motors, in which a spark occurs and an explosion takes place with *every revolution* of the shaft, have the timer or magneto driven at *crank-shaft* speed in single-cylinder motors, while multiple-cylinder motors of this type drive the magneto at double the speed of four-cycle motors of the same number of cylinders.

Odd as it may seem, an appreciable space of time elapses between the operating of the sparking device and the

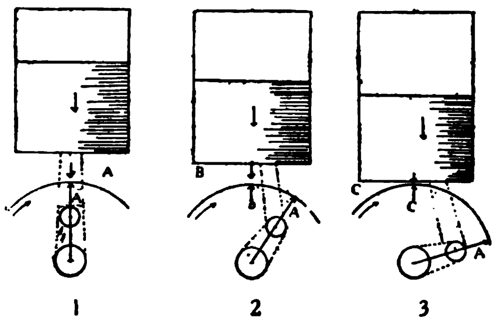


Fig. 41

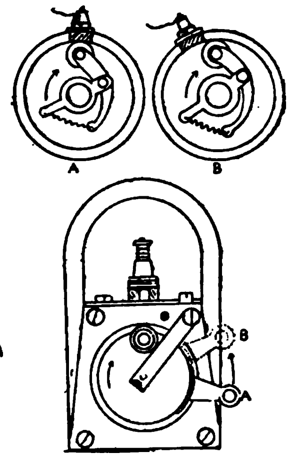


Fig. 42

actual occurrence of the spark within the cylinder, and, moreover, the gas does not ignite instantly when the spark does occur. This delay, or lag, makes very little difference when the motor is being started or when running slowly, but as the speed increases the lag remains constant and therefore later and later in relation to the position of the piston in direct proportion to the speed at which it travels. This can be more clearly understood by reference to Fig. 41.

In the diagram 1 the piston is shown just as it reaches the upward limit of its stroke, with the timer set to produce the spark at this point (A). If we assume that the spark does not actually ignite the charge until the fly-wheel and piston have reached the position shown in 2 we will see that the lag of the spark amounts to a space of two inches on the fly-wheel, as indicated at A to B, when it is moving at a given speed, say two hundred revolutions per minute. If the speed of the motor is now increased to four hundred revolutions per minute the face of the fly-wheel will travel just twice as far in a given time, and hence *four inches* of its circumference will have passed the upper center when the spark ignites the charge, as shown in diagram 3, A to C, and consequently the piston will have descended quite a distance in the cylinder, and only a portion of the force of the exploding-gas will be utilized and a great deal of power will be lost. Moreover, when the spark occurs very late a motor will heat up badly and will waste a great deal of fuel. To overcome this delay in ignition with increased speed means must be provided for altering the position of the sparking mechanism to correspond with the speed of the motor and overcome the lag in firing. This is readily done by having the timer, or the breaker of the magneto, movable, so that it can be rotated through a limited arc, as shown in Fig. 42, to correspond to the motor's speed. Thus, when a motor is moving slowly or is turned by hand for starting the timer is placed in the position shown at A, and the spark does not occur until the piston has passed the upward limit of its stroke; but as the motor speed increases the timer is pushed forward until the spark takes place some time before the piston reaches the upward limit of its stroke, as shown at B, thus counteracting the lag and producing an explosion which will exert its full power on the

piston. This varying adjustment of the timing device is known as *retarding* and *advancing* the spark, and upon it a great deal of the power, efficiency, and life of a motor depends. If a spark is advanced too far in starting, the explosion may take place before the piston reaches its upward limit and will *kick* back and injure the motor or perhaps maim the operator. If, on the other hand, it is advanced too far when the motor is running rapidly the motor may pound and lose power. Practice and experience are necessary to learn just the best point at which to set the timer for varying loads and speeds, and, as no two motors require exactly the same treatment in this respect, each operator must experiment until the best positions for the spark are determined.

Firing Sequence

All the above explanations of valve timing and firing refer to the simple single-cylinder motors, and where the engine is of the multiple-cylinder type the various valves must open and the sparks occur in the various cylinders in a definite sequence and relation to one another.

For example, a four-cylinder motor has an explosion in each cylinder at every fourth stroke of the piston; and, as there are four cylinders, this produces an impulse at each downward stroke of a connecting-rod, provided the timing is so arranged that the sparks occur and the charges are ignited in their proper order. In Fig. 43 A, a four-cylinder motor is shown in diagrammatic form, with the first cylinder at the firing-point. In this position No. 2 is at the bottom of the stroke, with the exhaust-valve open; No. 3 is at the bottom of the stroke, with both valves closed; and No. 4 is at the top of its stroke, with the inlet-valve open.

At this point No. 1 fires, and at the limit of its downward

stroke the various pistons and valves assume the positions shown in Fig. 43 B, with No. 1 at the bottom of its stroke and exhaust-valve opening; No. 2 at the top of stroke, with

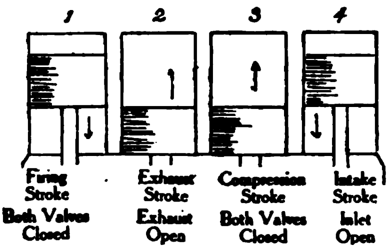


Fig. 43 A

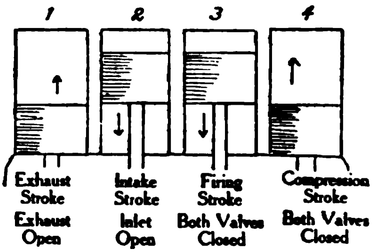


Fig. 43 B

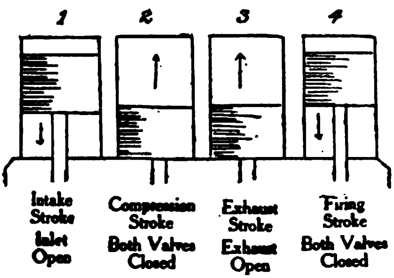


Fig. 43 C

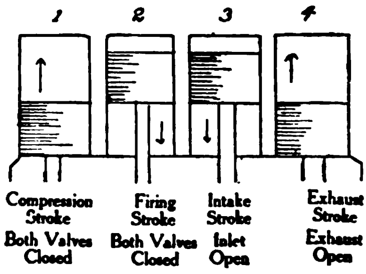


Fig. 43 D

inlet-valve opening; No. 3 at top of stroke, with both valves closed; and No. 4 at bottom of stroke, with both valves closed.

At this point the charge in No. 3 is fired, the piston driven down, and the various cylinders assume the positions shown in Fig. 43 C. No. 1 has now exhausted the burned gas and is starting on the intake-stroke; No. 2 has completed the intake-stroke and is starting on compression; No. 3 has fired and is ready to exhaust; and No. 4 has compressed the charge and is ready to fire. The spark now occurs in No. 4, and at the end of the stroke the various pistons are in the positions shown in Fig. 43 D, with No. 1 starting

compression, No. 2 ready to fire, No. 3 ready for the intake, and No. 4 ready to exhaust the charge it has just fired. The second cylinder now fires, and at the completion of its stroke the motor returns to the position shown in Fig. 43 A, with No. 1 again ready to fire.

Thus, the firing sequence of the motor illustrated is 1, 3, 4, 2, which is a very common sequence. Other motors fire 1, 3, 2, 4 or 1, 2, 4, 3, and by arranging the crank-throws as shown in Fig. 44 the cylinders may fire 1, 2, 3, 4 or 1, 4, 3, 2.

The object of every system of firing sequence is to produce explosive impulses alternately and to avoid idle or missed strokes of the pistons.

In the four-cylinder motor of the four-cycle type described above an explosion occurs on each down stroke, and thus

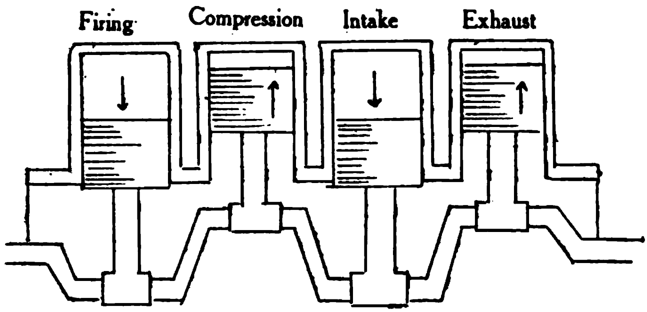


Fig. 44

the power and motion transmitted to the cranks and shaft correspond to the back-and-forth, or *reciprocating*, impulses of a single-cylinder steam engine.

As the crank-throws are set opposite at an angle of 180 degrees, each crank travels through 180 degrees, or half of a revolution, without an explosive impulse. To overcome this and produce an impulse at more frequent intervals

six-cylinder motors are used. The six-cylinder shaft has the cranks placed at angles of 120 degrees, and each crank travels through but one-third of a circle, or 120 degrees, without an impulse. This results in very smooth and regular action, with practically no vibration, for the force of an explosion is constantly being exerted against one of the cranks. In the two-cycle motor of two cylinders, with cranks at 180 degrees, the alternate explosions will produce exactly the same even action, or *torque*, as the four-cylinder four-cycle motor, and a three-cylinder two-cycle motor, with the cranks set at 120 degrees, will give as smooth-running and even action as the four-stroke motor with six cylinders, for the two-cycle motor receives an impulse at *each* revolution of the shaft for each cylinder, or *twice* as many as in the four-stroke type.

A two-cylinder four-stroke motor may be arranged to fire successively and receive an impulse on every stroke by attaching both cylinders to the same crank (Fig. 45 A), but this throws the engine out of mechanical balance and necessitates heavy counterweights in order to diminish the excessive jar and vibration. Any other arrangement in which this form of motor becomes mechanically well balanced must of necessity result in an idle or missed stroke, as shown in Fig. 45 B, or, in other words, there are *three* explosive impulses to every *five strokes*, or to every two and one-half revolutions. This would give but little better results than a single-cylinder two-stroke motor as far as even action and freedom from vibration are concerned, but by placing the two cylinders in a horizontal position, or *opposed*, as shown in Fig. 46, the explosions occur on each revolution exactly as in Fig. 45 A; but, as the explosions in one cylinder offset that in the other, very smooth action, with freedom from vibration, is obtained.

One very important item to be considered in connection with the operation of a gasoline motor is that of dead-centers. If we turn the crank of a single-cylinder motor until it is pointing straight up, as shown in Fig. 47, with the piston at the upward limit of its stroke, we can readily see that a

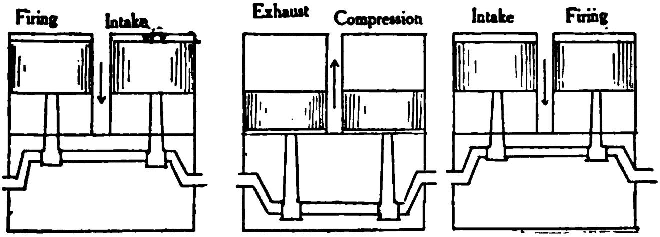


Fig. 45 A

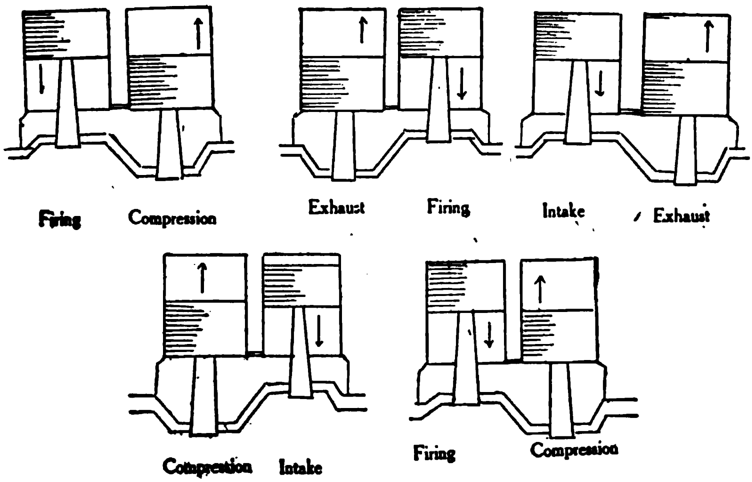


Fig. 45 B

straight downward pressure on the piston will have no effect upon the crank, and the same will hold true if the piston is at the lower limit of its stroke. These positions are known as dead-centers, and if the motor stops with the

crank on a dead-center an impulse exerted against it loses nearly all its force or leverage. To overcome this many motors are made with offset cylinders in which the piston is slightly at one side of the crank, but as a rule the momentum of the fly-wheel is depended upon to carry the shaft beyond the dead-centers. In a two-throw crank dead-centers still exist; but, as such a shaft is more or less balanced by the two cranks, there is less likelihood of the motor stopping on a dead-center. If the shaft has three or six cranks a dead-center can never exist, as one of the throws must always be a little beyond the point of dead-center and in a position where an impulse can exert a powerful leverage upon it (Fig. 48).

It is partly to overcome the tendency to stop on dead-centers that heavy fly-wheels are provided, the momentum of the fly-wheel helping to carry the crank, piston, etc., past dead-center. The fly-wheel also serves to force the piston up in the cylinder and exhaust the burned gas, to pull it down and draw in the fresh fuel, and to compress the charge ready to fire. In other words, the weight and momentum of the fly-wheel actually operate the motor through three strokes of the piston on a four-cycle motor and through one stroke of the piston on a two-cycle engine of the single-cylinder type. As the succeeding impulses of the three, four, or six cylinder motors serve to carry the idle pistons through their various strokes, a heavy fly-wheel is not required, and you will find that low-powered single-cylinder motors always have a much larger fly-wheel than the more powerful multiple-cylinder motors.

Even with a heavy fly-wheel the action of a single-cylinder motor is irregular and *jerky*, and to overcome this as far as possible counterweights or counterbalances are placed on most motors. There are various forms of counterbalances

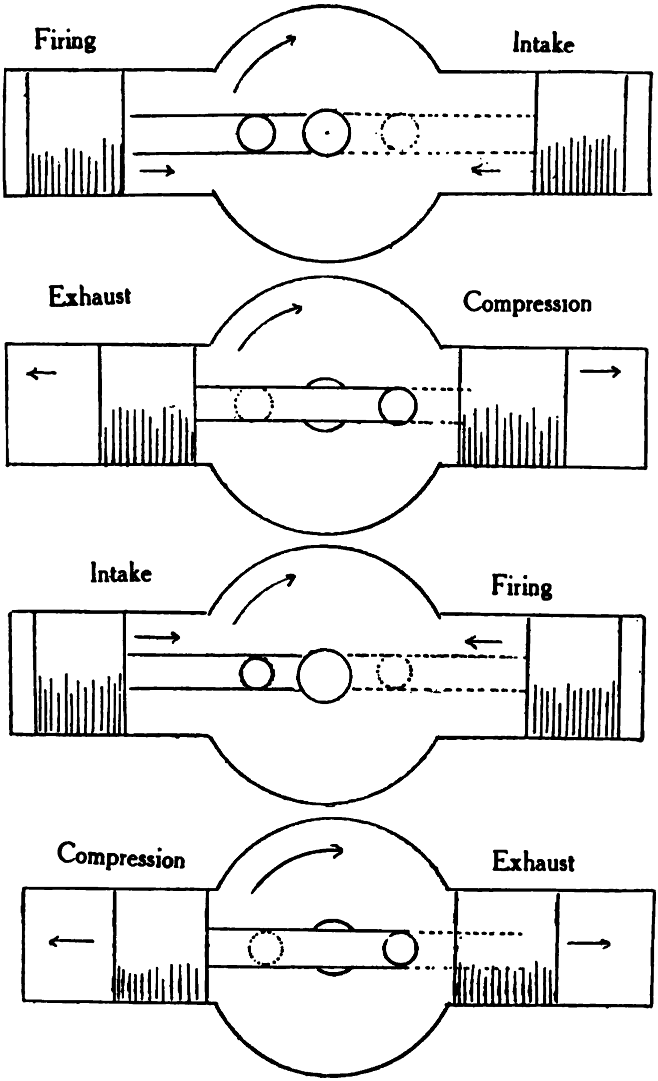


Fig. 46

TWO CYLINDERS IN HORIZONTAL POSITION, OR OPPOSED

employed, and each manufacturer has his own ideas as to the best method of attaching the weights. Some of the various means are shown in Fig. 49. Aside from true

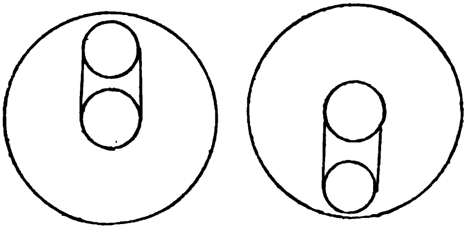


Fig. 47

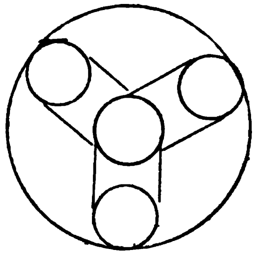


Fig. 48

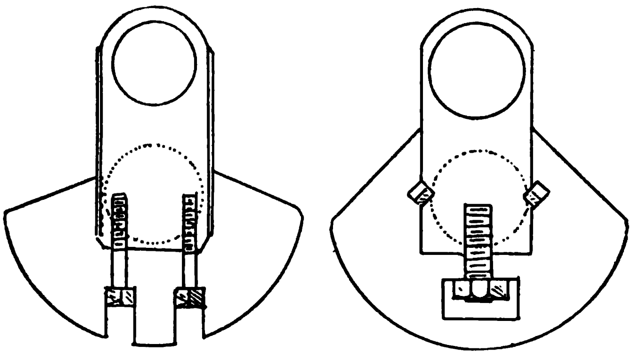


Fig. 49

counterweights, a great many motors have the fly-wheel balanced by holes drilled in one side to lighten it or with lead poured into holes to give greater weight. Weights attached directly to the crank are far better and more satisfactory, however, and this is the usual method adopted.

Chapter VII

SPECIAL FORMS OF MOTORS

THE novice will often be puzzled to classify certain motors which at first sight do not appear to be like any of the types I have described. There are such a vast number of gas engines made with so many minor variations and peculiarities that it is at times hard to grasp the exact principles of some motors. In every case, however, the modern motor is really a two or four stroke engine, and the principal differences lie in the arrangement of valves, ports, or similar parts. Two-cycle motors, as already described, are usually of the two-port or three-port types, but many of the more recent designs are constructed so that either a two or three port system may be used or the two may be combined in a single motor. Such a motor is shown in Fig. 1, in which the motor starts as a two-port engine and can be speeded up and operated as a three-port motor by opening the third port (A). Many of the best so-called two-port motors are in reality a sort of combination two-and-three port engine. In these motors—a section of one of which is shown in Fig. 2—the fuel is drawn into the by-pass (A), between the base and the inlet to the cylinder. This design has many advantages over the older type with the fuel inlet in the base, but its operation is exactly the same. By placing the inlet in the by-pass the suction of the piston is increased and the by-pass is warmed by the heat of the cylinder, resulting in better vaporization.

Other two-cycle motors are constructed with an open base, or, in other words, without the closed crank-case ordinarily seen. This method has decided advantages, for the crank-shaft, bearings, connecting-rods, etc., may be examined, adjusted, or oiled very easily, and all danger of loss of base compression is overcome. In order to construct a two-cycle motor with an open base various parts must be added and the height from top to bottom of the

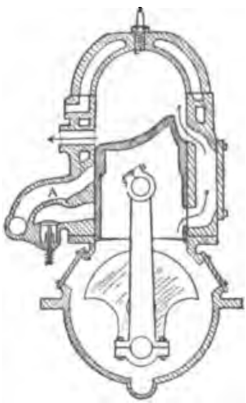


Fig. 1

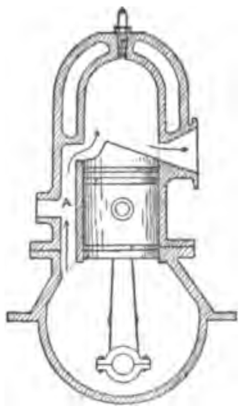


Fig. 2

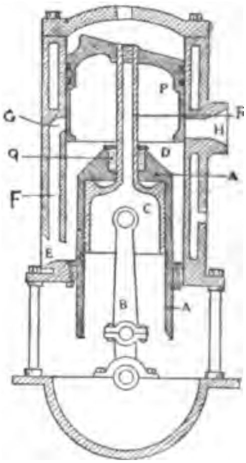


Fig. 3

engine greatly increased. This may be more readily understood and the constructive details grasped by referring to Fig. 3, which shows a sectional view of an open-base two-cycle motor.

The piston (P) is hollow, and below this and above the base is a piece called a *compression-plate* (A). Through the top of this compression-plate the piston-rod (R) slides in a tight packing (Q). Beneath the compression-plate this piston-rod is pivoted to the true connecting-rod (B) with a cross-head (C), which is a portion of the piston-rod itself,

and serves as a guide, sliding up and down inside of the compression-plate. On the upward stroke of the piston the gas is drawn into the space (D) between the piston and compression-plate through the inlet opening (E). On the downward stroke the gas is forced up through the by-pass (F) to the port (G), and hence to the top of the cylinder. After the charge is fired the exhaust gases pass out through the port (H) precisely as in the ordinary two-cycle motor. Aside from the advantages of the open-base construction this type of motor has greater initial compression than the ordinary two-stroke motor, and the cool charge of gas inside of the piston helps cooling, while the heat from the piston aids in vaporizing the charge. In addition there is no side-play or strain on the walls of piston or cylinder, as the piston-rod runs straight up and down, all the side-thrust being taken up by the connecting-rod and cross-head. For stationary or marine use these open-base motors are admirable, but as a rule their height is too great to permit of their general use in motor-vehicles.

Sleeve-Valve Motors

As all motors using poppet or similar valves are more or less noisy many forms of valves have been designed to overcome this objection and produce a noiseless motor. Among these devices are *rotary valves*, *piston-valves*, *sleeve-valves*, etc. Probably the best known and most successful of these are the sleeve-valve types, of which the Knight motor is the first and most widely used form.

In this motor, which is of the four-cycle type, the valves are in the form of pistons or sleeves sliding one within the other and placed between the piston and the cylinder, as shown in Figs. 4, 5, 6, 7. In Fig. 4 a cylinder is shown

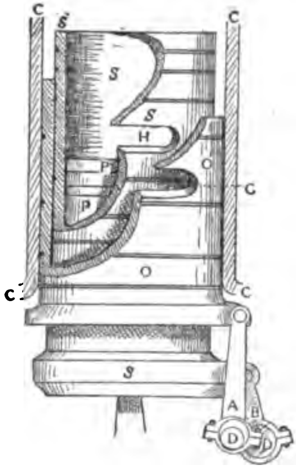


Fig. 4

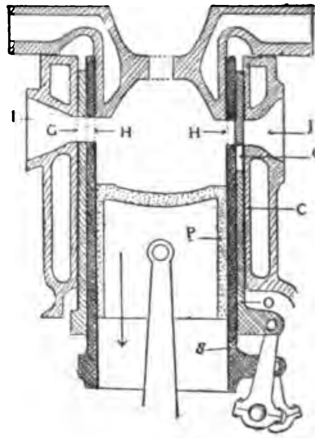


Fig. 5

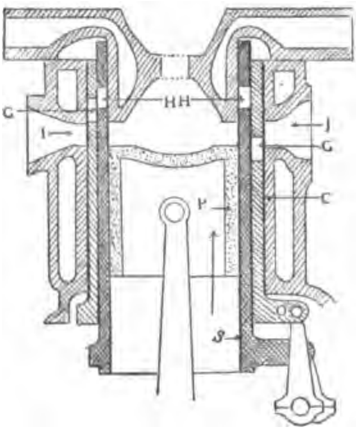


Fig. 6

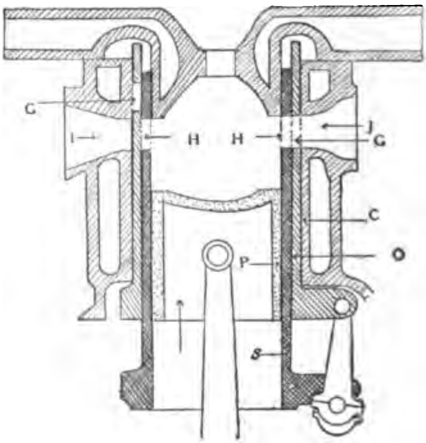


Fig. 7

partially cut away to expose the piston (P), the inner sleeve (S), the outer sleeve (O), and the cylinder walls (C). The two sleeves are attached to short connecting-rods (A, B) operated by eccentrics (D, D) on the gear-shaft, which is usually geared to the main shaft by a silent chain and sprockets.

Through the two sleeves are two ports, or openings (G, H), which slide past corresponding openings in the cylinder to allow the fresh gas to enter and the burned gases to escape. In operation the sleeve (O), sliding past the sleeve (S), brings the ports (G, H) opposite one another as well as in line with the inlet-port (I) (Fig. 5). These openings come into line on the commencement of the downward or intake stroke, and the charge of gas is drawn into the cylinder through the inlet-port thus exposed. At the commencement of the next upward stroke, or compression-stroke, the sleeves move into the position shown in Fig. 6, with the various openings (G, H, I, J) out of line and therefore closed against the escape of the gas drawn into the cylinder. The charge now is ignited, the piston driven downward, and as the lower limit of the stroke is reached the ports on the opposite side of the sleeves come into line with the exhaust opening (J) and allow the burned gases to be forced out, the two inlet-ports meanwhile being out of line, as shown in Fig. 7.

The sleeve-valve motor is practically noiseless, there is little wear, and all springs and weak *trappy* parts are eliminated. The sliding-sleeves, however, require very careful and plentiful lubrication, for if allowed to run dry they will bind and stick and overheat very rapidly. Moreover, the spaces between the sleeves, between the sleeve and the cylinder, and between the inner sleeve and the piston must be gas-tight, as the least wear or unevenness will allow the gases to escape and detract from the power and efficiency of the engine. If anything does go wrong the trouble and expense of repairs are much greater than in the ordinary poppet-valve motor, and it is doubtful if the sleeve-valve motor has any advantages over the more conventional forms aside from its quiet operation.

Another form of motor which has been very successful is the *piston-valve* engine shown in Fig. 8. In this motor the valve consists of a small piston (A) sliding in a special chamber (B) on one side of the cylinder. Near the center

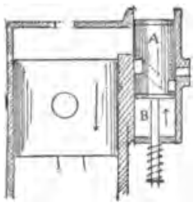


Fig. 8

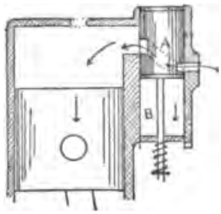


Fig. 9

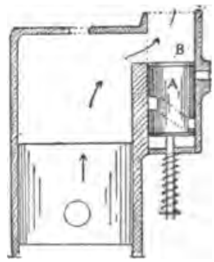


Fig. 10

of the piston-valve slots are cut through the valves and corresponding to the intake and exhaust openings in the cylinder. As the piston proper commences to travel down on the intake-stroke the valve slides up until the slots are in line with the intake, as shown in Fig. 9. The gas is thus drawn into the cylinder, and as the piston commences its upward compression-stroke the cam which operates the sliding valve allows the latter to drop, thus cutting off the openings and preventing the gas from escaping (Fig. 8). On the following downward or firing stroke the ports remain closed, but as the exhaust-stroke begins the valve slides farther down and leaves a space above it over which the exhaust gases are forced, as shown in Fig. 10.

This arrangement has a great many advantages. The valve is constantly cooled by the inrushing fresh gas, and, as the exhausted hot gases pass above it, they do not heat it appreciably. Moreover, the valve is constantly sliding up and down, so that no carbon can possibly accumulate to choke the openings. As there is but one valve to each

cylinder, there is very little friction and few mechanical parts. It is as silent as the sleeve-valve and simpler than the poppet-valve, and in case the valve wears and becomes leaky it can be readily lifted out and new rings inserted, no valve-grinding or adjustment being required.

Rotary Valves

Quite a number of motors are also made with rotating-valves which are very different from any of those described. There are two principal forms of rotary valves, one type having small, disk-like valves turning in seats in the cylinder-heads and the other type employing cylindrical tube-like valves revolving in hollow casings alongside of the cylinders. A motor using the former type is shown in Fig. 11, which represents the upper portion of the cylinders, with the valves (A, A, A) in position in cylinders Nos. II, III, and IV, and removed from the first cylinder. The valves (one of which is shown in the separate figure) are circular metal disks with openings (B), which correspond in size and shape with openings in the cylinder-heads (C, D). The valves revolve in recesses or seats machined in the cylinder-heads and are connected together above the cylinders by spiral or helical gears (E), which are operated by a vertical shaft and gear (F), which are in turn operated by a gear on the main shaft. On the intake-stroke of the piston the valves are turned until the opening (B) comes into line with the inlet opening (C) on the cylinder in which the piston is commencing the suction-stroke (position IV) and the charge of gas is drawn in through the opening thus formed. On the next or compression stroke the valve rotates until the inlet is covered (position II) and the charge is fired. At the termination of the firing-stroke the valve rotates

until the opening in the disk (B) uncovers the exhaust opening (D) (position III) and the burned gases are forced out.

This type of motor works very well, it is practically silent, there is scarcely any friction or wear, and the valves

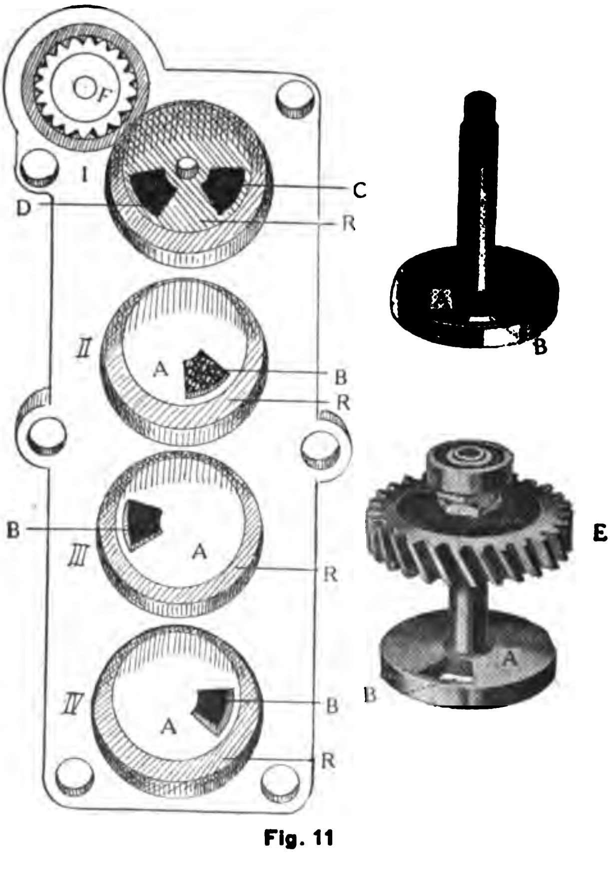


Fig. 11

are free from carbon troubles. In the other type of rotary-valve motor the valves are of tubular form, with slots cut in their sides to correspond with the inlet and exhaust openings in the cylinders. The valves revolve in a recess alongside

of the cylinders and are operated by silent chains from the crank-shaft. As the piston of one cylinder descends on the intake-stroke the inlet-valve revolves until the slot in the tubes comes into line with the intake-port. As it travels at one-half crank-shaft speed and the slot covers practically one-quarter of its circumference, the inlet-port remains open during the downward stroke of the piston and closes on the upward or compression stroke and on the following firing-stroke, after which the slot in the exhaust-valve commences to pass across the exhaust-port and remains open for practically half a revolution of the main shaft or one-quarter of a revolution of the valve. At the conclusion of this stroke the inlet-valve again opens for the suction-stroke. There are a great many variations of this type of valve, some makers using a single valve for both intake and exhaust, while others place both valves on one side of the motor, one above the other. Several very successful two-cycle motors are also made with rotating-valves; some of them employ the disk type and others the tubular. In the case of two-cycle motors the valves are slightly different, and their operation may be more satisfactorily mastered by studying the diagram shown in Fig. 12. Some two-cycle motors have the rotary valve at the intake only, with an ordinary open exhaust-port; others use valves at both intake and exhaust, while still others use a large rotary valve in the base as a *distributer* and force the charge of gas through this mechanism to the various cylinders in their proper order. The well-known Elmore motor is of this type, and a portion of the base of a cylinder with the rotary valve or distributer is shown in Fig. 13. The piston (A) is much larger at the lower end than at the upper, and this enlarged lower end acts as a fuel-pump, alternately sucking in the gas to fill the space (H) and forcing it out under pres-

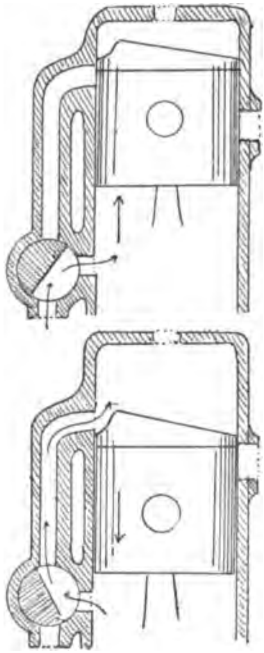


Fig. 12

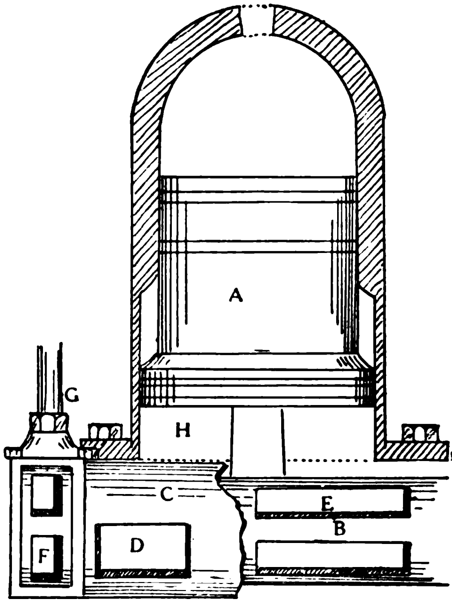


Fig. 13

sure through the distributer. As the compressed gas is forced out by the downward motion of the piston, it does not pass directly to the top of the same cylinder, as in the ordinary two-cycle motor, but is led to another cylinder by the valve or distributer (B). This arrangement, which is an essential feature of the motor, consists of a revolving cylinder (B) within the casing (C). The chambers thus formed are provided with lengthwise openings, or ports, those of one chamber opening on one side of the distributer (D) and those of the other opening on the opposite side at E. The distributer is driven by a silent chain from the crank-shaft and is supported on spindles and ball-bearings. In operation the lower half of a cylinder receives its charge of gas

through the slit in the outer chamber of the distributer, and on the down stroke this gas is returned to the inner chamber, from which it passes into the firing-chamber of the cylinder whose piston is on the upward or compression stroke. The firing and exhaust are accomplished exactly as in the ordinary two-stroke motor, and the operation is repeated in each cylinder in proper order, giving four explosions or impulses to the shaft, the cranks being placed at 90-degree angles. An important detail of the distributer construction is that the inner chamber (B) is divided into two equal parts by a partition in the center. These two portions are connected by the by-pass (F), which may be opened

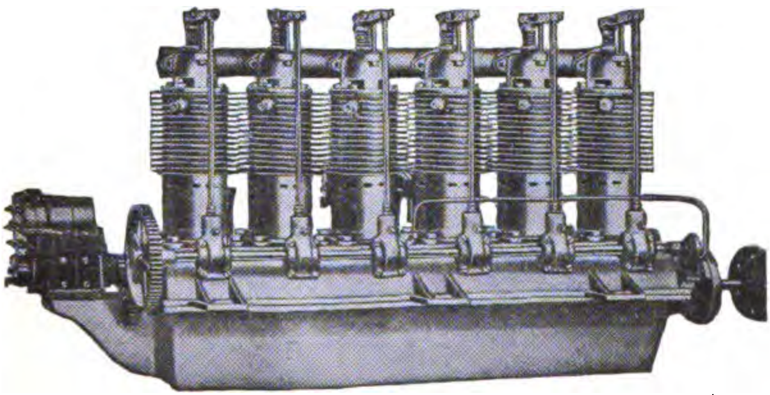


Fig. 14

or closed at will by the throttle (G). Until this throttle is more than half open the two halves of the distributer operate like two separate motors and the cylinders work in pairs. As the throttle is opened farther the central control opens automatically, and all four cylinders operate alternately.

Rotary valves in four-cycle motors do away with a great

many noisy, troublesome parts, such as cams, cam-shaft, valve-guides, springs, tappets, rocker arms, etc., but they are liable to wear and leak compression, and any such trouble is far more difficult to remedy than the ordinary

Fig. 16

Fig. 15

poppet-valve. In the case of two-cycle motors the rotary valve insures more accurately regulated charges and freedom from back-firing, but it adds a number of mechanical parts to the motor.

Arrangement of Cylinders

The majority of gas engines are of the vertical-cylinder type, in which the cylinders are placed one behind the other along the upper side of the crank-case (Fig. 14). Many two-cylinder motors are also made with the cylinders horizontal, or *opposed* (Fig. 15), and many motors designed for special purposes are of the *V form* (Fig. 16), with the cylinders placed at an angle with the shaft. More peculiar in their arrangement are the odd *star* or *radial* motors (Fig. 17), while most remarkable of all are the *rotating*

motors, in which the cylinders revolve and the shaft remains stationary.

No matter what arrangement of the cylinders may be adopted for a motor, the principle and operation are identical with the ordinary vertical form, the position of the cylinders being adopted merely to save weight and space.

When the cylinders are arranged vertically the size and weight of the crank-shaft, crank-case, and other parts must be in exact proportion to the cylinder capacity, and the addition of every cylinder will add a proportionate length and weight to case and shaft. This fact is clearly illustrated in Fig. 18, in which A shows a two-cylinder vertical motor and B a similar motor with four cylinders, in which the crank-case must be twice as long as in A. By placing the four cylinders in V form, as shown in Fig. 19, with each pair of cylinders coupled to a single crank, the four cylinders may be placed on a case but very little longer than in the two-cylinder vertical motor. Almost the same result may be obtained by placing the cylinders horizontally, or op-

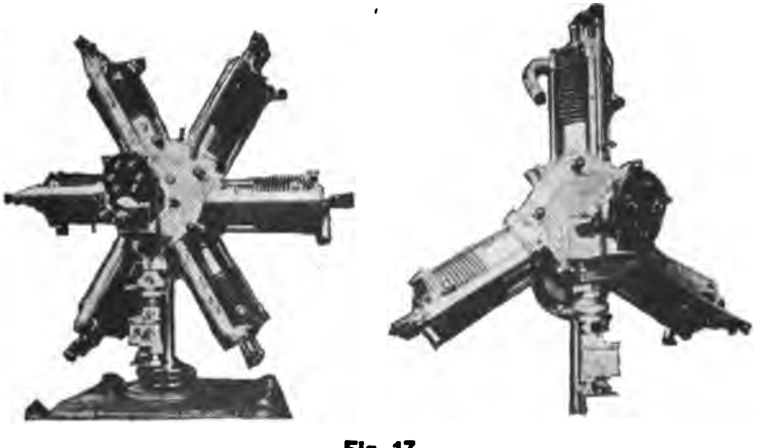


Fig. 17

posed (Fig. 20), but this arrangement makes the motor very wide and impracticable for many uses. This objection may be overcome and the crank-case length and the weight still further reduced by placing the cylinders in star form, with the four connecting-rods attached to two cranks (Fig. 21). By using counterbalances all four connecting-rods may be attached to a single crank, but, as counter-weights are an objection and add weight without additional power, more cylinders are added to take their place, and the motor becomes a true radial form (Fig. 22). In this motor

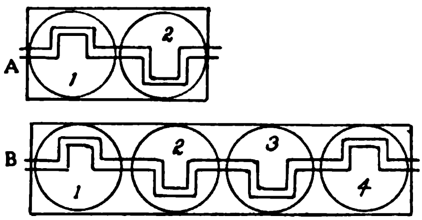


Fig. 18

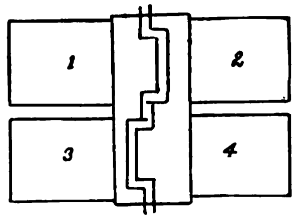


Fig. 20

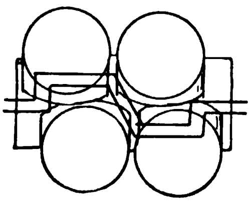


Fig. 19

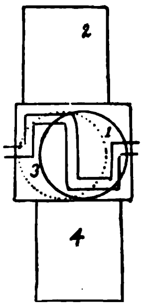


Fig. 21

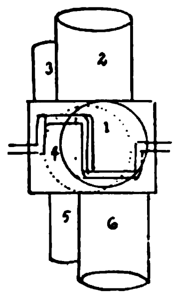


Fig. 22

there are two crank-throws with three connecting-rods fastened to each, and thus a six-cylinder motor is obtained, which is no longer and has very little more weight than the two-cylinder vertical motor of one-third its power, shown in Fig 18, A. Such radial or star motors have a

very serious fault, which is that the oil will invariably flood the lower or bottom cylinders. To overcome this trouble the three lower cylinders may be placed on top of the case without appreciably adding to its length or weight.

These V-shaped and radial motors are just as simple, reliable, and efficient as the vertical form, and are far more powerful in proportion to size and weight. They are widely used in speed-boats, motorcycles, and in the latest of motor-vehicles—the cycle-car—as well as in aeroplanes, but for aviation purposes they have many specially designed features and details of construction.

Aeroplane Motors

The most highly perfected of all gasoline motors are the wonderful engines that drive the modern airship. Although so highly developed, yet the conditions under which the aviation motor works are so severe and unusual that it is next to impossible to make a motor that will be absolutely reliable.

Whereas the automobile engine is constantly varying in its work and seldom operates at maximum power or speed, the aeroplane motor is called on for its extreme power all the time that it is in operation.

To withstand this strain the strongest and most wear-resisting materials must be used in its construction, and unfailing methods of lubrication and cooling are necessary.

As an aeroplane motor must be exceedingly light in weight and free from vibration and must be operated on a most fragile and insecure bed, you can readily imagine how difficult it is to combine these various requirements of an aviation engine.

It is very easy to construct a reliable motor fairly free

from vibration and with long life, provided it weighs from eight to fifteen pounds or more per horse-power, and few automobile or marine motors weigh less than this. But think what it means to build a motor of the same reliability, power, and life, and weighing but 2-1/2 to 5 pounds per horse-power; or, as a better illustration, think of a six-cylinder 60-horse-power motor so light in weight that a man can readily lift it in his hands! Yet this is accomplished in many aviation engines, and the wonder is that aeroplane motors are one-half as reliable as they are.

In place of the cast iron, heavy forgings, stout, long bearings, heavy supports, and thick cylinder walls of the marine or automobile motor, the engine for aerial use is constructed of the highest-grade chrome and vanadium steels, magnalium metal, manganese bronze, and similar materials, with delicate ball-bearings, feather-weight crank-cases, and cylinder walls hardly as thick as ordinary card-board.

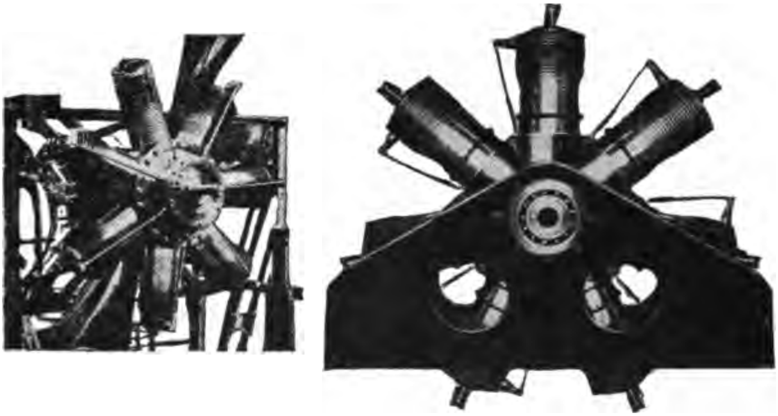
This means a very high-priced motor, for no part can be slighted and the best possible work and the utmost care must be devoted to each and every part and detail. Some idea of the work required to construct a modern aeroplane motor may be obtained by considering the crank-shafts and cylinders of any one of the better aviation engines.

These parts are machined from solid steel bars, and the crank-shafts in the rough may weigh as much as two hundred pounds, but when finished weigh less than twenty-five pounds. Many air-cooled engines have the cylinders turned and bored from solid steel or iron bars six inches or more in diameter, and yet the completed cylinder weighs but a few ounces and is less than 1/16″ in thickness.

The time and labor required to turn down and finish the numerous parts of such a motor make it extremely

expensive; and whereas a good auto or marine engine may be purchased for $100 to $300, a fairly reliable aviation motor will cost from $1,500 to $6,000, or more than the complete boat or automobile, engine and all.

There are a great many types, models, and forms of aeroplane motors in use, some good, some fair, and some



A Fig. 23 B

worthless, and among them are both two and four cycle motors, air and water cooled motors, and motors of vertical, opposed, V, and radial forms.

As space and weight are primary considerations for aviation purposes, the majority of aeroplane motors are made in forms which economize space and weight to the extreme. This demand for extreme light weight and high speed with great power, combined with the fact that cost is of little consideration in aviation, has led to the construction and adoption of the remarkable rotating-motors.

These rotary engines are pre-eminently airship motors and are of practically no value for any other purpose. There are numerous makes of these motors, and, while they differ

slightly in minor details, yet they are so similar in operation and principle that an explanation of one will serve for all.

The Rotating-Motors

Probably the best known of all rotating-motors is the famous *Gnome* (Fig. 23, A), but the *Gyro* (Fig. 23, B), which is made in America, is very much like it and in some details is much superior.

A diagrammatic section of the Gyro is shown in Fig. 24, with a section of one of the cylinders in Fig. 25.

In this motor the crank (S) is fastened immovably, and the various cylinders are attached to a case which revolves freely around the shaft and is mounted on ball-bearings. Within the cylinders are pistons (P) attached to the connecting-rods (R), the lower ends of which are all fastened to a single crank (X) on the shaft.

By the explosion of a charge of gas in the cylinder (1) the force compels the cylinder, with the case attached, to travel *away* from the crank, as the crank itself is immovable.

As the cylinders and case revolve the crank, being eccentric to the center, or shaft, pulls the piston in cylinder (2) downward, thus drawing a fresh charge of gas into that cylinder. At the same time the piston in another cylinder (5) is being forced up to compress the charge, which is then fired and forces the entire assembly around the shaft, and thus in rotation each cylinder fires its charge and helps force all the cylinders around the central shaft.

By reference to the diagram (Fig. 24) it will be seen that, whereas the cylinders revolve around the shaft in the circle Y, the pistons and connecting-rods revolve around a center formed by the crank in the circle Z. In this way actual up-

and-down or reciprocating motion is overcome, and the motor is practically free from jar and vibration.

The exhaust-valves are in the heads of the cylinders, as shown in Fig. 25, and are operated by push-rods, which are moved by their lower ends passing over stationary cams.

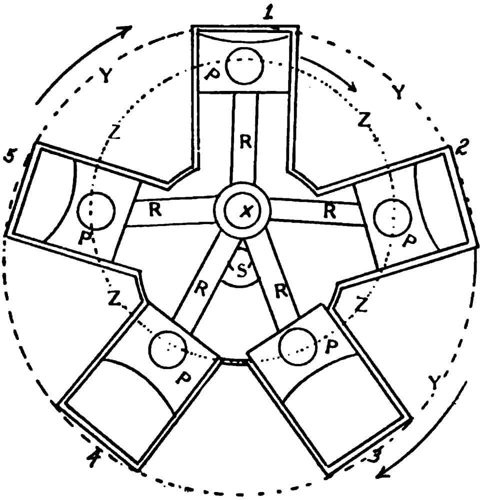


Fig. 24

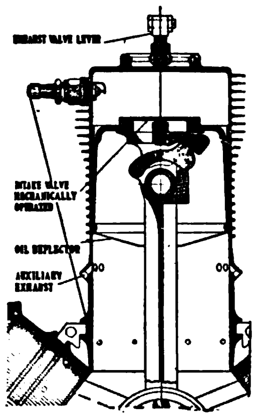


Fig. 25

The intake-valve is situated in the top of the piston, and is opened by a metal dog which is operated by the centrifugal force of the revolving cylinders.

The crank-case serves as the inlet for the fuel, and the entire motor is thus very simple and free from complicated parts.

A very distinct form of rotating-motor known as the *Justrite* has the cylinders fastened parallel with the shaft. Rotation is obtained by the pistons acting upon small pinions meshing with a large stationary gear, and, as this gear cannot revolve, the small pinions, cylinders, and casing revolve around it and the central shaft.

In this form of motor (Fig. 26) there are no real valves, for each cylinder receives and exhausts its charge by merely passing by openings, or *ports*, connecting with a chamber at one end of the motor. One-half of this chamber is the intake, the other half the exhaust, and as the cylinder which has just fired passes by the opening in the exhaust-chamber the burned gas is expelled. It next passes the intake-port, and a fresh charge is drawn in.

Ignition is accomplished in an equally simple manner by means of a brush-contact wiping by a plate, and thus practically all wiring, a complicated timer, and other ignition apparatus are eliminated.

This motor has proved very successful, and, unlike most aeroplane motors, it is so strong, sturdy, and powerful, and

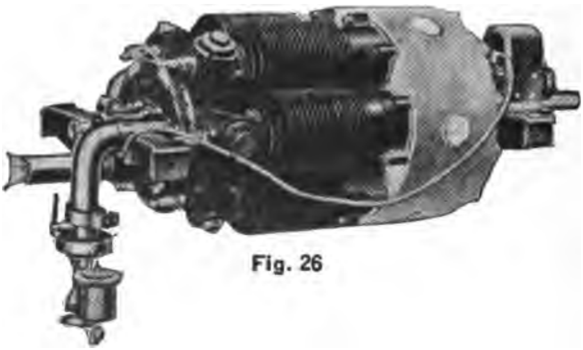


Fig. 26

so free from ordinary troubles and breakdowns, that it has been used considerably in trucks and automobiles.

Practically all the rotating-motors are air-cooled, and, as the cylinders of these motors travel so rapidly through the air, this method is very satisfactory.

Chapter VIII

SIZE AND POWER OF MOTORS

THE size of a gas engine is usually denoted by the term *horse-power*. Thus we hear of "10-horse-power motors," "40-horse-power motor-cars," "60-horse-power engines," etc. This term is in a way confusing and a misnomer, for a "mechanical horse-power" is merely a term adopted as a standard unit and denotes the power required to lift 550 pounds 1 foot in 1 second, or, as more often expressed, the power to lift 33,000 pounds 1 foot in 1 minute. If you hear of an automobile of 60 horse-power it does not necessarily follow that such a machine would be able to pull as large a load as sixty real horses, although it might easily travel far more rapidly than sixty horses pulling the same load. In fact, the horse-power of a motor may be so altered by gearing and other devices as to produce greater speed and less power or greater power and less speed, exactly like any other mechanical power.

The indicated power of a motor depends upon several factors. The most important of these are the bore, stroke, and speed. Other matters, such as ignition, fuel, quality, and adjustment, proper lubrication, and the compression of the gas in the cylinders, affect the power considerably. In computing horse-power these various matters are considered as constant, and only the bore, stroke, and speed are considered, and the power computed from these factors is

known as *indicated horse-power.* The whole of the indicated power is never actually available, however, for a large part of it is consumed in overcoming the friction of the moving parts of the motor, and the power remaining and actually available is called the *delivered horse-power.* The proportion of this delivered horse-power to the indicated power is known as the *mechanical efficiency,* and is usually expressed in per cent. Thus, if the indicated horse-power of a certain motor is 10 horse-power and the delivered power is 6 horse-power, the *mechanical efficiency* would be 6/10, or 60 per cent., and the *friction load,* which is overcome by the difference between the two, would equal 10−6, or 4 horse-power.

The pressure of the gas under compression in the cylinders of a motor varies considerably with different motors and various fuels, but the average pressure has been established as about 70 pounds to the square inch. With these factors known it is a very simple and easy matter to ascertain the horse-power of any motor with reasonable accuracy.

For four-cycle motors: D. H. P. equals diameter of cylinder multiplied by itself, times length of stroke, times revolutions per minute, divided by 18,000, times number of cylinders.

Example: The D. H. P. of a motor with 3″ bore, 3″ stroke, and operating at 1,000 revolutions per minute would be 3×3=9×3=27×1,000=27,000÷18,000=1-1/2 H. P.

For two-cycle motors proceed in the same manner, but divide by 13,500.

Example: A two-cycle motor with 3″ bore and 3″ stroke operating at 1,000 revolutions per minute would show 3×3×3×1,000=27,000÷13,500=2 D. H. P.

The so-called A. L. A. M. rating for automobile engines is merely an arbitrary rule depending upon the bore, without considering speed (which is assumed to be constant and

1,000 revolutions per minute), or the stroke, which is a most important matter.

The rule for computing A. L. A. M. ratings is as follows:

Bore multiplied by itself times number of cylinders divided by 2.5.

Example: An engine of 4″ bore with 4 cylinders would show $4 \times 4 = 16 \times 4 = 64 \div 2.5 = 25.6$ H. P.

In order to prove the fallacy of this rating as a means of actually determining the horse-power of a motor we may proceed as follows:

Suppose the motor is four-cycle, has four cylinders, is of 3″ bore and 3″ stroke and operates at 1,000 revolutions per minute. According to the D. H. P. formula, the equation would be $3 \times 3 \times 3 \times 1{,}000 \div 18{,}000 = 1\text{-}1/2 \times 4 = 6$ D. H. P.

If the same type of motor with 4″ stroke is computed, we find the equation as follows: $3 \times 3 \times 4 \times 1{,}000 \div 18{,}000 = 2 \times 4 =$ 8 D. H. P.

Under the A. L. A. M. rating the first motor would show 14-2/5 horse-power and the second the same amount, which would be far in excess of the actual horse-power of either motor.

Where the actual power of a motor is to be determined the motor is tested by some form of pressure-brake, and the D. H. P. thus determined is known as *brake horse-power.* Such tests are accurate and reliable, but you must always bear in mind that motors undergoing factory tests are operated under the best possible conditions. They are handled by skilled engineers and mechanics, are furnished with the best oil, fuel, and ignition, and are tuned up and adjusted to the utmost.

The same motor that delivers 10 brake horse-power in a factory test may not develop over 6 horse-power when installed and operated under working conditions, and yet

it may show fully 18 horse-power by any of the various formulæ.

This misunderstood subject of horse-power ratings has led to a great deal of confusion and disappointment, and before judging the actual power of a motor or its suitability for a certain purpose you should know its bore, stroke, speed, weight, valve area, etc. The fact that a great many foreign cars which have a very low rating are excessively fast and powerful has proved a puzzle to many people. In reality a foreign motor which rates at only 18 or 20 horse-power by A. L. A. M. rating may have an unusually long stroke, very large valve areas, and may operate at extremely high speed, and if the horse-power was worked out with these factors included the horse-power indicated might be 30 or 40.

Large heavy motors seldom operate at high speeds and are suitable for heavy, steady duty. As marine motors and stationary motors must deliver a constant amount of power at uniform speed for hour after hour, the motors best adapted for such work are slow-moving, heavy motors with large bore and long stroke. Vehicle motors, on the other hand, work intermittently and are seldom compelled to deliver their full power except in hill-climbing, and under such strains they transmit their power through gears. For these reasons comparatively light, high-speed motors are used with small bore, short stroke, and more lightly constructed and accurately made parts.

Each type of motor is adapted to some special purpose, and each type of vehicle, boat, or machine requires a motor adapted to it in order to produce the best results.

A marine motor will not prove satisfactory in an automobile, and few vehicle engines would be serviceable for marine use, while the most highly perfected motor of all,

the modern aeroplane motor, would be a complete failure and would soon break down under the conditions to which many boat and automobile motors are constantly subjected. This fact has led to gas engines being developed along several distinct lines, and, as each of these differs materially from the others, they should be considered separately, with their various attachments, accessories, and fittings.

Part III

MARINE AND STATIONARY MOTORS

Chapter IX

THE MARINE MOTOR

IN a general way marine motors resemble those of any other type, but in many details, accessories, and attachments they are quite different.

The engine of a motor-boat is subject to a great many conditions which never occur to a vehicle or stationary motor. They are constantly exposed to severe weather, such as fog, spray, mist, and salt-air, and are seldom given half the care or attention bestowed upon other motors. When operating they are continually called upon to deliver their full power, and as a rule they are left idle and uncared for for many months at a time, often unprotected from the weather and invariably surrounded by damp and musty coverings or boards.

When we consider the extremely severe and unfavorable conditions which surround the marine engine it is remarkable that they are half as serviceable as they are.

Most marine engines are far simpler than similar types used in automobiles, and many of the attachments and accessories are dispensed with. Radiators and other intricate or delicate cooling systems are not required, for marine engines have a constant and reliable source of cooling close at hand. The pump is merely connected with a pipe opening beneath the water-line of the boat and the outlet from the water-jacket led out through another pipe. Both

rotary or gear pumps and plunger-pumps are used in marine engines, and in either case a strainer of some sort must be provided at the outside end of the intake-pipe. If such a strainer is not furnished bits of seaweed, dirt, mud, etc., will invariably work into the pump and clog the valves or the pump or even fill up the water-jacket and prevent circulation and cooling.

When a marine motor is to be used in salt-water all the pipes, fittings, connections, and the shaft should be of bronze or brass, and even for fresh-water use such metals are preferable to iron. A great many marine motors, especially in small boats, are connected directly to the shaft and propeller, but in the larger sizes and better kinds of boats a clutch or *gear* is provided.

The object of a clutch or gear is to enable the motor to run idle without turning the propeller, as well as to enable the operator to reverse the motion of the boat readily. When the engine is connected with a clutch or gear it may be started and adjusted while at the dock or wharf, and when making a landing or short stops the engine may be throttled down and allowed to run while the boat remains at rest, thus obviating the nuisance of stopping and starting the motor each time the boat itself is stopped. By the use of gears the boat may be reversed or driven ahead at will, and by allowing the clutch to slip slightly almost any desired speed may be obtained.

There are a great many forms of clutches and gears used, but they are all far simpler than the clutches and transmissions used in automobiles. Marine gears, as a rule, are of the planetary type, with one forward and one reverse speed, although many speed-boats and racing craft use gears with several speeds. One of the most popular forms of clutch and gear used in motor-boats is of the planetary

pinion and gear type illustrated in Fig. 1. In this clutch the engine-shaft (A) is keyed to a plate or drum with internal teeth (B) which mesh with two or more pinions (C) attached or pivoted to another drum (E). Through this latter drum the propeller-shaft passes and bears upon its forward end a pinion or gear (D) meshing with the pinions (C, C). On the outer surface of the drum (E) is a brake-band (F) which operates through a lever (I). Upon the rear end of the drum (E) friction-disks (J) are keyed, alternating with

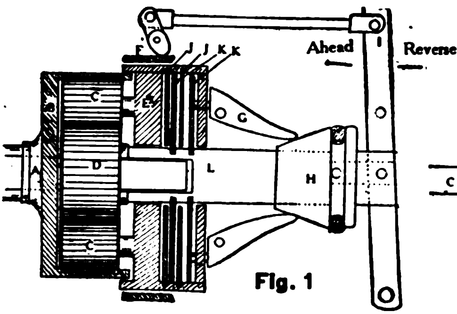


Fig. 1

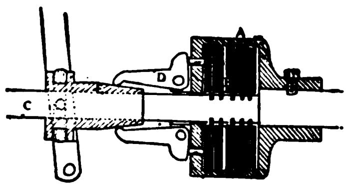
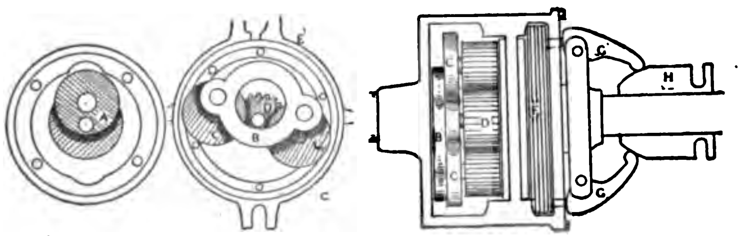


Fig. 3



A B C

Fig. 2

other disks (K) keyed to the propeller-shaft (L), and which may be forced together by the dogs (G, G), and the cone (H), which is operated by the lever (I).

When the lever is in an upright position, as shown in the diagram, the drum (B), with the pinions (C) and drum (E), revolve idly around the shaft (L), and no motion is imparted

to the propeller. By pulling back on the lever the brake-band (F) is pressed against the outer surface of the drum (E) and prevents the latter from revolving. As soon as this occurs the pinions (C, C) transmit the power of the engine-shaft through the pinion (D) in a reverse direction, thus reversing the propeller. By pushing the lever (I) forward the friction-disks (J, K) are forced together, and the shaft (L) and the drum (E) become practically one piece, and as the brake (F) is released the internal gear on the drum (B) causes the entire clutch and shaft to revolve in the same direction as the motor. The objection to this form of gear is that the engine transmits its power through small pinions on the reverse, and these pinions, moving much faster than the driving-shaft, wear rapidly and become very noisy.

To obviate these objectionable features a form of gear has been devised in which an eccentric serves in place of the internal gear. A section of this gear, which is known as *Joe's gear* and is widely used, is shown in Fig. 2. The diagram (Fig. 2, A) shows the forward end of the gear with the eccentric (A), while Fig. 2, B, shows the rear end with the eccentric ring (B), two gears (C, C), the propeller-shaft gear (D), and the brake-band (E). Fig. 2, C, is a side view of the gear, showing all the above parts, in addition to the friction-disks (F), the dogs (G), and the sliding-cone (H). In operation the eccentric (A) revolves within the ring (B), which is connected to the pinions (C, C) by pins. The rotary motion of the eccentric moves the ring back and forth, and thus turns the pinions which mesh in the driving-gear (D) and cause it to turn in a reverse direction when the brake-band is drawn against the drum by the lever. The friction-disks (F) are keyed alternately to the shaft and case, and are brought into tight contact by the dogs (G) and the cone (H) when the lever is swung forward.

In a great many cases reverse-gears are not required on small boats, and a simple one-way clutch enables the operator to run his motor idle and to stop his boat without stopping the motor. A one-way clutch is far simpler than a gear, and a sectional view of one is shown in Fig. 3. This clutch consists of a case or drum (A) fastened to the motor, within which are a shaft and number of metal disks (B) alternately fastened to the case and to the propeller-shaft (C), and which are brought into contact by the dogs (D) and the sliding-cone (E). When the lever is brought back and the dogs are released the engine shaft and case revolve freely, but as soon as the lever and cone are thrown forward the friction of the disks causes the power to be transmitted from the case to the propeller-shaft.

Shafts and Universals

No matter how stiff and stanch a boat may be, there is always more or less give and play in the timbers and planks, especially in a heavy sea, and even with the strongest and firmest engine timbers the vibration shakes the boat more or less and allows the engine to move slightly. In small boats with light, low-power motors this does not amount to much, but in larger craft and where high-power engines are used means should always be provided for preventing this *jump* of the motor from being transmitted to the shaft. If a solid and rigid shaft is used the motion of the motor must necessarily cause it to bend and buckle, and this strain will rapidly loosen the bearing, or *stuffing-box*, where the shaft runs through the stern, and will cause the entire boat to vibrate and shake. When a clutch or gear is used there is some play between the ends of the driving and propeller shafts, and this takes up a good deal of the

vibration and motion of the motor. It is far better, however, to place a *universal joint* of some sort between the motor and the propeller. Universal joints are rather expensive, but they save their cost many times over in wear and tear, not to mention comfort and freedom from vibration. A universal joint of a very simple form is illustrated in Fig. 4, in which the two ends of the shafts are

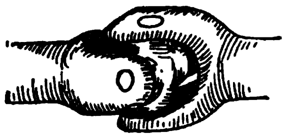


Fig. 4

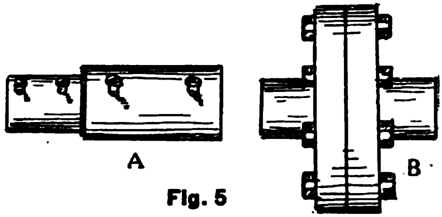


Fig. 5

connected by a cross-shaped pivot which allows the shafts to revolve freely, even when considerably out of line. This form of joint serves very well on small sizes of shafting, but on large boats a more durable and flexible joint should be used.. The principle of all such joints is the same, however, and, no matter how complicated they may appear, the object of all is to provide a shaft connection which can move readily in any direction while the shafts themselves are revolving.

When a straight, rigid shaft is used the greatest care should be taken in installing it, for if it is the least bit out of line there will be undue friction and you may find it impossible to start the motor; or, after it is started, you may find that a large portion of the power is wasted in overcoming the friction, while the whole boat pounds and shakes horribly. It is truly surprising what a small amount of friction on a shaft will prevent a motor from operating. I have seen a large yacht with a powerful motor stalled because the shaft

was a fraction of an inch out of line. A shaft, even on a big boat, should turn perfectly freely by hand, and if it binds in the slightest degree when the engine is turned over the motor should be lined up until it turns smoothly throughout its revolution. In connecting shafts on boats various forms of couplings are used. Among these are *sleeve-couplings* (Fig. 5, A) and *flanged couplings* (Fig. 5, B). The latter are by far the best, for they can almost always be disconnected without difficulty. Sleeve-couplings are very liable to become so corroded on the shafts that the latter cannot be drawn out, and even if the shafts are not corroded the keys often are. Flanged couplings may become corroded, but even if the connecting-bolts cannot be unscrewed they can always be sawed off and driven out, thus allowing the shafts to be separated. When putting any form of couplings together the various parts should be given a coat of graphite or black-lead and grease to prevent them from rusting or corroding together.

Mufflers and Silencers

Mufflers or silencers are devices designed to muffle or silence the loud explosions of the exhaust gases escaping from a gas engine. Unfortunately, many of these devices fall far short of their intentions, and the exhaust, after passing through them, is nearly as noisy as before. The modern automobile motor is usually muffled until practically silent, but in nine cases out of ten this is accomplished through the loss of considerable power. The burned gases leave the cylinders of a motor at a speed of from 6,000 to 12,000 feet per minute, with a pressure of from 25 to 35 pounds per square inch. As the pressure and speed rapidly diminish as the temperature decreases and the gases expand, it is quite possible to entirely silence their noise if a muffler or

chamber of sufficient size is provided to enable the gases to entirely lose their pressure and speed before reaching the open air.

Unfortunately, *expansion chambers* of sufficient capacity for this purpose would be impossible in most cases, and in order to bring about the same results with smaller devices various mechanical and artificial means are used to more rapidly cool and expand the gases and to compel them to expend their force before being allowed to escape.

If the gases are held back by restricted or obstructed passages or openings there will be considerable back pressure on the motor, with a consequent loss of power, and it is really a difficult matter to design a compact and efficient muffler which will not cause back pressure. As the gases contract very rapidly upon cooling, and thus lose their power and speed, a great many mufflers or silencers employ special means for rapidly cooling the gases. For marine engines this is a simple matter, as there is always an abundance of cool water on hand, and the water may be led through a jacket around the muffler, or even directly into it.

There are a great many forms of mufflers in daily use, but the principle of all is similar and consists in mechanically breaking up or dividing the exhaust gases, and in thus causing the gases to issue from the muffler in a more or less steady stream instead of in a succession of puffs or explosions. A very simple method of accomplishing this is shown in Fig. 6, and consists of a shell or case within which are two perforated tubes. The exhaust enters through one of these tubes, is broken up by passing through the small holes, and expands in the space around the tubes before passing out through the perforations in the other tube. Another simple form in common use is illustrated in Fig. 7. This form, known as a *baffle-plate muffler*, has the interior

fitted with several perforated plates through which the gases pass and are broken up in the same manner as in the perforated-tube system. Other mufflers employ a combination of the two systems, as shown in Fig. 8, which illustrates the *Yankee* muffler. A much better form, known as the *ejector* muffler, is shown in section in Fig. 9. This device consists of three

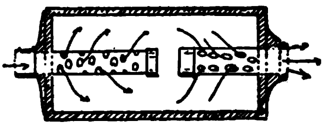


Fig. 6

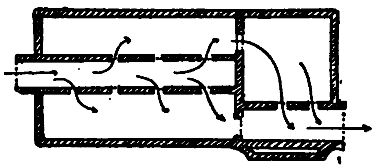


Fig. 8

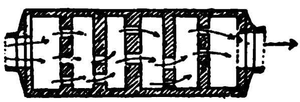


Fig. 7

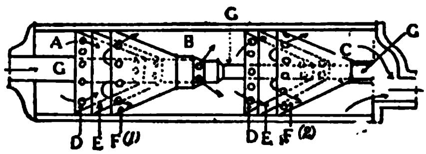


Fig. 9

expansion chambers (A, B, C) separated by conical plates (D, E, F), perforated at their tops and bottoms and arranged in two sets. The middle tube (G), leading straight through the whole, is of varying diameter, and a portion of the gas from the motor rushes directly through the tube to the central chamber (B) and from there through the second set of cones [D, E, F (2)], before the gas which enters the chamber (A) has had time to pass through the first series of cones [D, E, F(1)]. A very small part of the gas is also led clear through the central tube (G) to the outlet. This creates a partial vacuum in the third chamber (C), and the gas moves quickly from the second space (B) to fill this vacuum. The forward movement of the gas is through the first and second chambers (A, B) to the third (C) and creates a sudden

expansion which cools them and reduces the pressure in the muffler to a point below that of the atmosphere, thus allowing the gas to escape with practically no noise and very little back pressure.

Where any of these various forms of silencers are used on boats very much better results, less back pressure, and a cooler muffler are obtained by running a small portion of the water from the jackets into the muffler. As water-cooling in this way proves so very satisfactory, a number of silencers are made especially for marine use with devices for circulating water through them. Among such devices are the *Hydrex* and *Thermex* silencers, illustrated in Figs. 10 and 11. In the Hydrex (Fig. 10) the gases enter at A and are turned upward and given a whirling motion by the internal cone (V). Water from a jacket enters at B through a ring-shaped

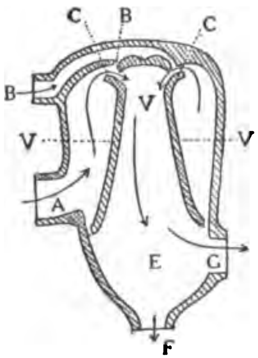


Fig. 10

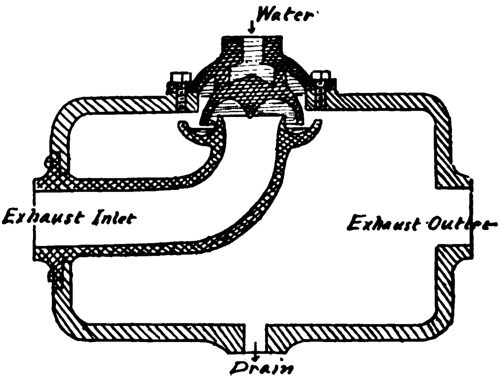


Fig. 11

aperture which forms a circular sheet of water flowing into the inverted cone (V). The gases travel upward on the outside of the cone and pass through this sheet of water, and are turned down into the inside of the cone by the lips (C). By striking the water the gases are instantly cooled and expand

in the chamber (E) and pass out through G, while water which may accumulate within the chamber is drained out at F.

The Thermex works on a very similar principle, and is so plainly shown in the diagram that no explanation is required.

Whenever any water is led into the muffler great care should be taken to place the latter several inches lower than the motor cylinders and to have the silencer slope away from the motor, with an outlet or drain at its lowest point. If this is not attended to you will always have trouble. If the muffler is higher than the engine the water is very liable to work back into the cylinders or valves, and if the muffler does not slope or has no opening at its lowest point water will accumulate and soon rust out the muffler. Moreover, wherever water is used in a silencer the latter should be of non-rusting material or heavy galvanized iron.

A great many marine motors are not equipped with silencers at all, but lead the exhaust gases out from the boat beneath the water-line. This is a very simple method, and entirely eliminates noise, but it must be properly done unless you want lots of trouble.

With small motors this method is hardly advisable, as there is quite a little back pressure when starting or traveling slowly, but with large motors, especially four-cycle engines, an under-water exhaust is excellent. Whenever an under-water exhaust is used an expansion chamber should be placed close to the motor. This is merely a cylindrical tank or case which is much larger than the exhaust-pipe and allows the hot gases to expand and cool slightly before being led out under water. From the expansion chamber the pipe should be a size larger than from the motor to the chamber, and it should be led as straight and as directly as possible. Avoid right-angle joints, use 45-degree elbows, and be sure

that the motor-exhaust opening is well above the water-line of the boat. At the highest point of the exhaust-pipe place a relief-cock (Fig. 12), and place a drain-cock at the lowest portion of the expansion chamber. A shut-off valve should also be placed between the outlet of the pipe and the chamber, for, no matter how carefully the exhaust is installed or how far above the water-line the motor may be, there is always a chance that the boat may be partly filled with rain or may leak until it settles so low that water will back up into the motor and fill the boat. When not in use this cock should always be shut off. It is also a good plan to connect a three-way cock with the exhaust-pipe (Fig. 12), so that when starting or when additional power is required the exhaust may be turned straight out to the open air.

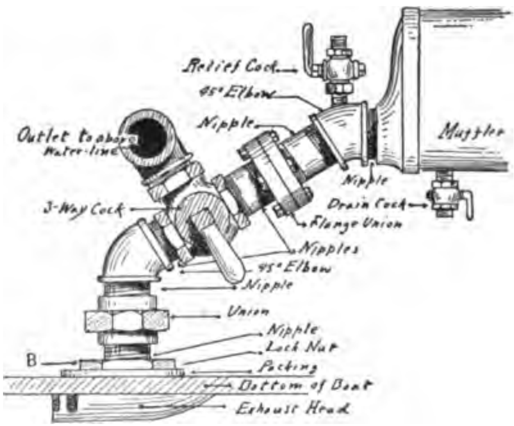


Fig. 12

Where the pipe passes through the bottom or side of the boat under water a device known as an *exhaust-head* should be used. This serves to prevent the water from drawing into the end of the pipe, and when moving rapidly a partial vacuum is formed behind it, thus allowing the gases to escape more easily. When starting the motor with an under-water exhaust the relief-cock at the highest part of the pipe should always be opened, as otherwise steam or water may be drawn back into the cylinders when turning

the motor over by hand. Sometimes a considerable amount of water will collect in the pipes and expansion chamber, and in cold weather this will freeze and cause damage. It is a good plan to drain the chamber every day with the cock provided for that purpose.

The various connections to be used and the method of making them will, of course, vary with the boat, its shape, the position of the motor, etc., but the principle is fully illustrated in the sample under-water-exhaust installation illustrated in Fig. 12.

Installation of Marine Motors

A great many marine motors are very carelessly or improperly installed, and this applies not only to the exhaust connections, but to the water-pipes, fuel-pipes, wiring, and even to the engine-bed equally.

As already noted in a previous paragraph, it is impossible to find a boat which is perfectly rigid and which will not permit the motor to move or vibrate to some extent in a heavy sea or when under unusual loads. For this reason every joint of a pipe and every wire connection should be firm and strong, and where pipes pass through the boat some means should be furnished to provide flexibility. The shaft may be rendered flexible by clutches, gears, or universal joints, and in expensive boats pipes may be fitted with flexible unions, elbows, etc., but in most boats short sections of heavy rubber hose may be used for the same purpose. The connections in the water-pipes should be made very carefully, for a small air leak in the intake will often cause the pump to fail, and a leak in the outlet is disagreeable and allows water to run into the boat. Connections should be made with white or red lead and oil, sharp turns should be

avoided, and drain-cocks should be provided at the lowest points of all pipes.

Where pipes enter the boat below or near the water-line shut-off valves should be placed, for many a boat has filled and sunk through a loose or broken connection and no valve to shut off the water.

Fuel-pipes require special care, as a very small leak in the gasoline line may result in fire or loss of life, for a very small leak will often allow enough gasoline to leak into a covered boat to blow it to atoms.

In making up the joints in the fuel-pipe shellac or laundry soap should be used, as lead, paint, or any material containing oils is useless. At least a part of the pipe for the fuel should be of soft copper, with a turn or coil to allow

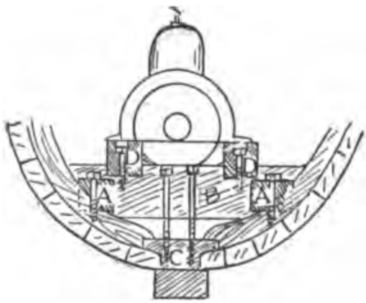


Fig. 14

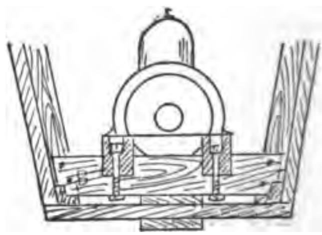


Fig. 15

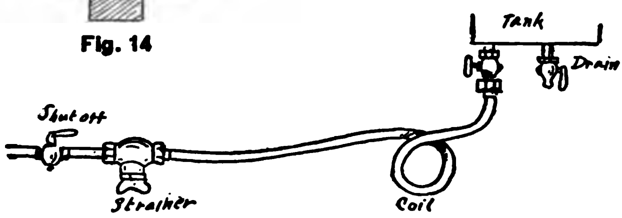


Fig. 13

flexibility (Fig. 13), and the pipe should be frequently examined for signs of leakage. A cock should always be placed close to the fuel-tank to allow it to be shut off quickly,

and a strainer should be placed in the line to catch dirt, sediment, or water. Lead or block-tin pipe should never be used, as it is easily bent or crushed, it is liable to be punctured, and it forms scales and sediment which work into the carbureter. Moreover, in case of fire it melts quickly, thus allowing more gasoline to escape and feed the flames.

No matter how much care you use in your shaft, exhaust, water-pipe, and fuel-pipe installation, your labor will be wasted if the engine-bed is improperly made or the motor is insecurely fastened to it.

The exact method of making an engine-bed in a boat is governed to a great extent by the size and form of the boat, the position and size of its timbers, the accessibility of the location, and other factors. The timbers for making the bed should be of well-seasoned hardwood, of ample size and strength, and should be securely bolted to the ribs and keel, but *not to the planking.* A very good method is to use two long timbers running lengthwise, or fore and aft, of the boat and fastened securely to the ribs (A, A, Fig. 14). Across these other timbers (B, B) should be fitted, and bolted to both the long timbers (A, A) and the keel (C). On top of these cross-timbers the engine-bed proper (D, D) may be fastened. In flat-bottomed boats timbers may be set across the boat, bolted to keel and sides, and the engine-bed bolted on top of these (Fig. 15). This method takes the jar and vibration from the floors and planks and furnishes a very rigid bed.

The motors should be attached to the bed timbers by lag-screws, and these should be large enough and long enough to hold the motor firmly in place. Under the heads of the screws washers should be placed, and the screws should be set up just as tightly as possible. Any looseness or play between the engine-base and the timbers will result in the

screws loosening, and, moreover, the wood of the bed will pound down and the motor will become looser and looser.

In placing the motor on its bed attention should be given to accessibility; every part of the motor, especially such parts as may require attention or adjustment, should be open and where you can easily reach them. The carbureter, oilers, crank-case, drain-cocks, pipe connections, and bearings should all be visible without having to stand on your head or tear up flooring or other fixtures, and the space around and under the motor should be free from cracks and holes through which bolts, nuts, tools, or other articles may fall. If there is crack, hole, or inaccessible spot anywhere near an engine you may be sure that any object you drop will find it. It is a very good plan to place a zinc, brass, or galvanized-iron pan under and around the motor. This will catch all grease, oil, water, etc., and is easily cleaned and will prevent the floors and timbers from becoming soaked with grease and oil.

A marine motor, more than any other, should always be clean, handy, and accessible, with room for inspection or adjustments on every side. It is a mighty disagreeable job to lie in a cramped position in the bilge-water in a seaway to adjust or repair some slight matter, and this can always be avoided by taking a little care in installing the motor properly in the first place.

Care and Handling of Marine Motors

A great deal of the success or non-success of a motor depends upon the care or attention given it, and with marine motors this is of far greater importance than with any other type of engine.

A great many owners of gasoline motors appear to think

that if they furnish oil, gasoline, and electricity the motors should continue to run and deliver their full power without any other attention. Because gas engines *do* require so little care as compared with other forms of machinery they are woefully neglected. Gas engines are really very highly perfected and delicate pieces of machinery, and the amount of abuse and neglect which they will withstand is most remarkable, and is the highest testimonial to their sturdiness and efficiency.

The idea that a motor is an obstinate and balky object and must give trouble is a myth and pure nonsense. If a motor is properly cared for and runs smoothly for one hour there is no reason why it should not run for weeks, months, or even years, and if it fails to do so it is positive proof that some matter has been neglected or requires attention or adjustment. As a rule most of the troubles with motors are really the fault of the operator, and a little common sense and a knowledge of the motor and its requirements will accomplish far more than a lot of hit-or-miss tinkering and revilement of the motor.

There is some excuse for a vehicle motor giving out unexpectedly, for it is hidden under a hood out of sight, and until it actually fails the operator dislikes the messy job of looking it over and cleaning it. A marine motor, on the other hand, is exposed and within easy reach, and it can be constantly watched and inspected. Nevertheless, marine motors, as a rule, give more trouble than vehicle motors, and this is usually due to the operators themselves. One often sees a person, running a motor which is working smoothly, continually tinkering with screws, nuts, and adjustments in an endeavor to get more speed or power from the engine. Pretty soon the motor skips and stops, and the operator, being perfectly ignorant of the cause and for-

getting the original adjustments of the parts, tries one thing after another, and usually makes the matter worse and worse. When he finally gives it up as a bad job he blames the motor and calls it obstinate and balky. In the automobile the operator cannot fool with his motor as long as he is driving the car, and as a result the motor gives but little trouble aside from ordinary wear and tear.

Every piece of machinery wears out in time, and the more it is neglected and abused the sooner it will give out.

If you wish long life and continued service from your motor give it painstaking care and attention, and do not fool with it unless you are a complete master of its principles, construction, and repair.

First, keep your motor clean. If you allow grease, oil, rust, and dirt to accumulate the motor will soon be troublesome, and, moreover, it is harder to clean up a dirty motor than to keep it wiped off and free from dirt each day.

Whenever the paint or enamel gets chipped or worn off and rust shows, clean the parts with gasoline and give it a coat of engine enamel. Keep the brass or nickel parts clean and bright; if you do not have time to keep them polished, wipe them frequently with an oily rag or waste and prevent verdigris from forming.

Whenever you see a loose nut, screw, or bolt, tighten it up, and if badly worn or rusty replace it with a new one.

See that the wires are dry and are not loose, broken, or rubbed, and clean the connections to engine, plugs, switch, and batteries if they show any signs of corrosion. Provide good tools, and keep them clean and handy. Do not try to force your engine; a motor can only deliver a certain amount of power, and if you want more speed than your motor can produce you must get another motor.

Clean your spark-plugs frequently; if your cylinders

become foul with carbon, have them scraped or cleaned out; and if you hear any unusual sound, such as a rattle, knock, or pound, stop the motor at once and do not operate it until you have located and remedied the trouble, unless you are in dangerous waters where a stop may imperil your safety or that of your craft. *Do not* touch the carbureter, valves, or ignition apparatus until they give trouble, and don't touch them even then unless you are positive that you understand how to remedy the trouble.

Remember that 90 per cent. of motor troubles are due to faulty ignition, and in case of trouble *always* look over the wiring, batteries, plugs, switch, etc., before touching anything else. If you disconnect a wire from the plug and turn the motor to the firing-point and a bright spark occurs when you touch the wire to the motor, you may be sure that the trouble is not in the batteries, the primary wires, the coil, or the switch. By removing a spark-plug and placing it on top of the motor and attaching the wire to the plug and then turning the motor to the firing-point you can easily determine if the trouble is in the plug itself. If no spark shows, try a new plug. If the spark shows thin and irregular, clean the plug with gasoline and adjust the points until about 1/32" apart. If you see small sparks inside of the plug it shows short circuits from dirt or soot. If a new plug or a clean one does not improve the spark, try adjusting the vibrator-points on the coil slightly. A bright purplish or reddish spark is a good spark; a thin blue one is poor.

If the spark appears good try priming the motor by placing a little gasoline in the cylinders and turning it over by hand. If the priming charges fire it proves that the trouble is *not* in the ignition.

Marine motors are particularly prone to electrical troubles, for it is almost impossible to protect the wires, batteries,

etc., from dampness. Have your batteries under cover in a water-tight box or case, keep your wires well above the bilge and where they will be as dry as possible, and cover the entire motor with a water-proof cover when not in use.

If you attend to these various matters, use common sense at all times, and study the requirements and operation of your engine, you will seldom have trouble. If any difficulty arises which you cannot master, call in a competent engineer or mechanic who understands marine motors. Many good auto mechanics and chauffeurs are completely at a loss where marine motors are concerned, just as many splendid marine-motor operators are useless about an automobile.

Chapter X

STATIONARY MOTORS

ALMOST any fairly good motor, whether of the marine or automobile type, can be used for operating machinery of various kinds. For a great many purposes such motors serve every purpose, but where even and steady service and economical operation are desired a motor designed and built for stationary work should be used.

Stationary motors may be of either the two or four cycle types, of any number or size of cylinders, and either horizontal or vertical. As a rule they are built in one-cylinder forms even when of large size, and horizontal motors are more popular than vertical, and most of them are of the four-stroke type.

Whereas unnecessary size and weight are objectionable features in vehicle or marine motors, they are an advantage for stationary engines. A heavy, sturdy motor is steadier, there is less jar and vibration, and it is not necessary to provide such a steady bed or to bolt it as securely as when a light engine is used.

Except for special purposes a long-stroke, slow-speed motor is better for stationary work than a short-stroke, high-speed motor. The slower motion is more readily controlled, a very large fly-wheel can be used to steady the motion, and any desired speed can be obtained by pulleys and belts.

The horizontal form is superior to vertical forms for stationary use, as it gives a wider, longer, and more stable bed in proportion to the height from the floor and permits the use of a large fly-wheel without unduly increasing the height.

The construction, principle, or operation of a true stationary motor is in no way different from marine or vehicle motors of the same class, but the stationary motor is far simpler. As these motors operate at a fixed and invariable speed, the various devices for increasing or decreasing speed are done away with and automatic governors are substituted.

As stationary motors are placed under cover in buildings, very little care need be given to the protection of tanks, pipes, wiring, etc., and a very simple cooling method may be used. Many stationary motors have a large tank over the cylinder and forming a part of it, and this tank contains the water which thus completely surrounds the cylinder at all times. As the water next to the cylinder becomes heated it rises and the cooler water sinks, in this way keeping up a continuous circulation about the cylinders.

Other water-cooled stationary motors when placed in factories or shops merely have the city water-supply pipes run to the water-jacket and the water is allowed to flow around the cylinders when the motor is running. A great many motors for stationary use are of the air-cooled type, and these give very satisfactory service.

Governors

A very important portion of the stationary motor is the governor. This is a device for automatically controlling the speed of the motor, and without some such device a

stationary engine would require constant attention and would have to be continually throttled down and speeded up by hand as the various pieces of machinery were or were not operated.

By using a governor the motor operates at a constant speed under all conditions, and it may be regulated to work at any desired speed within its capacity. There are various forms of governors, some very simple and some quite complicated, but they are all easy to understand once their principle is grasped.

There are three principal methods of governing motors, known as *hit-or-miss*, *throttling*, and *varying ignition*. The first controls the motor by shutting off the fuel-supply, opening or closing the exhaust-valve, stopping ignition, or preventing the valve mechanism from operating. The operation of the throttling governors is to reduce the charge drawn into the motor, while the varying-ignition system varies the advancement or position of the spark or shuts off the electrical current.

A form of hit-or-miss governor which operates upon the valves is shown in Fig. 1. When the motor is released

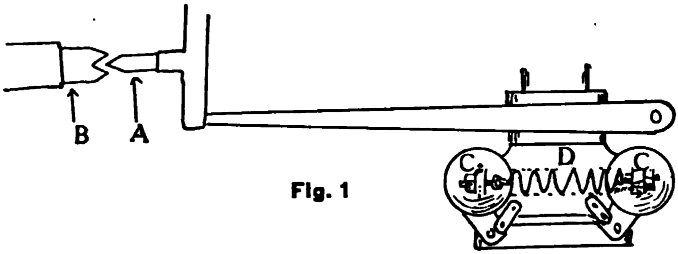


Fig. 1

from its load and begins to race or operate beyond its normal speed the balls (C, C) spread apart by centrifugal force, thus causing the blade (A) to move away from the notched valve-lifter (B), in this way throwing the valve out

of action until the motor slows down to its desired speed. By loosening or tightening the spring (D) the governor may be adjusted to operate at any desired speed.

Another form of governor which acts directly upon the valves is illustrated in Fig. 2. In this device if the motor

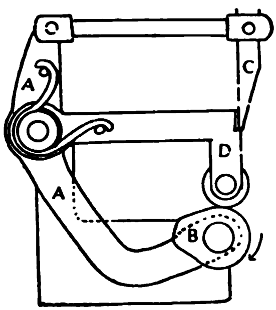


Fig. 2

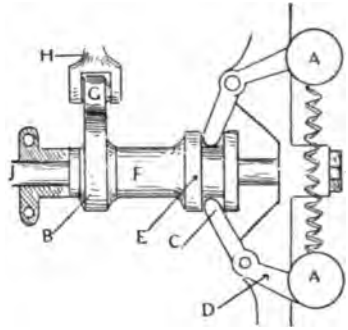


Fig. 3

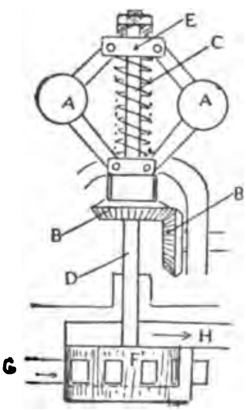


Fig. 4

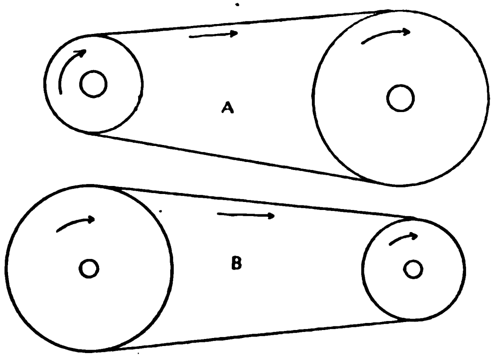


Fig. 5

runs above normal speed the lower end of the double lever (A) is depressed by the cam (B), and the valve-lifter (C) is at once thrown out of contact with the notch (D), thus preventing the valve from operating until the engine slows down to the speed for which the governor is adjusted. Still a third

type of valve-controlling governor is shown in Fig. 3. When the speed of the motor exceeds that for which the governor is adjusted the balls (A) swing outward by centrifugal force and cause the cam (B) to move to the right by the action of the levers (C) on the arms (D). The cam is thus withdrawn from its contact with the valve-lifting roller (G), and the valve remains closed until the speed is reduced, and the action of the spring between the balls overcomes the centrifugal force and brings the cam back into contact with the roller.

A very different form of governor which may be employed with any method of control, but is especially adapted to throttling, is illustrated in Fig. 4. With an increase of speed above normal the balls (A, A) swing outward and compress the spring (C) and push down the spindle (D) by means of the collar (E). As the spindle slides down the valve (F) moves down also, thus slowly cutting off the charge of fuel entering through the openings (G, H).

In the varying ignition systems of governing the action is very similar to that of the devices described, and in almost every case the control of the motor's speed is obtained through weights or balls which swing outward with centrifugal force and are held in their normal position by adjustable springs.

Power Transmission

As the governor of the motor will control the speed of the engine and will cause it to operate at a fixed number of revolutions per minute, the adjustment should be so made as to provide the most desirable speed. This will depend upon the size and power of the motor and the purpose for which it is used. If the motor operates but one or two machines which run at a fixed speed it is very easy to connect the motor to them and govern its speed accord-

ingly. Usually, however, a motor is used to operate a number of different machines which may run at various speeds and may consume more or less power, according to their size and purpose.

In such cases the desired speed and power for each machine must be obtained through the transmission devices. Power is usually transmitted from the motor to the machinery it operates by means of belts and pulleys, and by varying the size of the pulleys any desired speed or power may be obtained.

If the driving-pulley is smaller than the one driven the latter will move slower than the driving-pulley (Fig. 5, A), whereas if the driving-pulley is the larger of the two the speed of the driven pulley will be increased (Fig. 5, B). The increase or decrease of speed thus obtained will be in exact proportion to the size of the pulleys. Thus if the driving-pulley is one-half the diameter of the driven pulley the latter will move at one-half the speed of the former, and if the driven pulley is one-half the diameter of the driver it will move just twice as rapidly. In each case where the speed is increased or decreased there is a corresponding loss or gain in power. An increase in speed means a loss in power, and a decrease in speed means a gain in power. This is an unalterable law of physics, and every user of a motor or of any form of mechanical device should always remember it. It does not make any difference whether the increase or decrease of speed is obtained through gears, belts, chains, or other transmission devices. In every case the result will be the same, aside from the loss due to friction or slip according to the method of transmission employed. Bearing these facts in mind, you can readily understand that from a motor operating at a certain speed you can transmit power to various machines running at a number of different

speeds and requiring more or less power. If your machines are arranged near together it is a very easy matter to transmit the power from your motor. By placing a shaft above the motor and furnishing this shaft with pulleys of various sizes you can obtain various speeds from a single line of shaft. This is illustrated in Fig. 6. The engine pulley (A) is connected to a much larger pulley (B) on the overhead shaft,

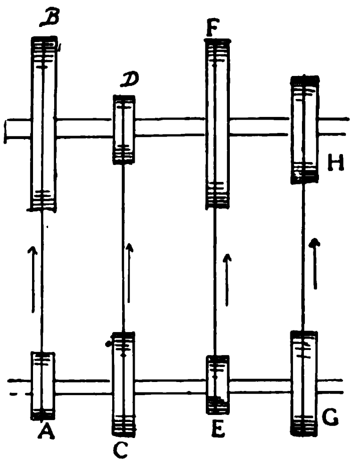


Fig. 6

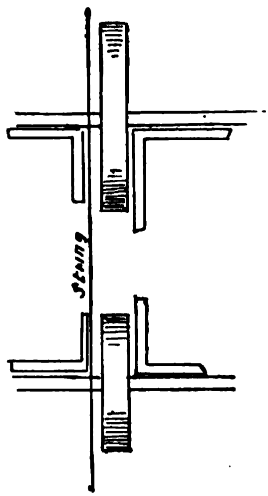


Fig. 8

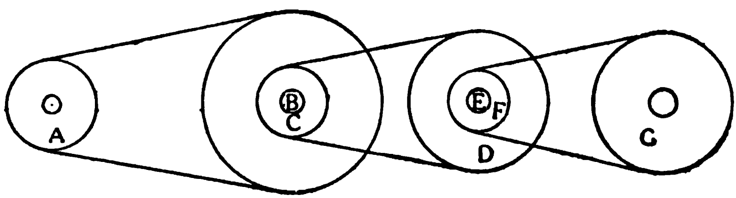


Fig. 7

and this large pulley drives the shaft slowly, but with much greater power than that of the motor. Pulley (C) is attached to the same shaft as (B), and revolves at the same speed, but

the belt from this pulley is led to a very small pulley (D), thus causing the latter to revolve at tremendous speed, such as would be required for an emery-wheel or similar tool. Still farther on the shaft is pulley (E), which is very small, but, being attached to the same shaft as (B), it revolves slowly. From (E) a belt is led to a large pulley (F), which it turns very slowly but with great power, suitable for a heavy lathe or other slow-moving powerful machine. Still another pulley (G) on the shaft has its belt running to another pulley of the same diameter (H), and the latter will move with exactly the same speed and power as the pulley (G).

Where several machines may be placed close together such an arrangement is very handy and simple, but in many cases it is necessary to have the several machines widely separated or even in different rooms. In such cases various shafts, countershafts, and other devices must be employed to transmit the power, carry it around corners, reverse the motion, etc.

It frequently is impossible to use a single pulley large enough to reduce or increase the speed the desired amount between two shafts. Under such circumstances the desired result may be accomplished by using a train of pulleys (Fig. 7). In this diagram the driving-pulley (A) is connected by belt to a large pulley on the other shaft (B). On this driven shaft is another small pulley (C), which in turn is connected to a large pulley (D) on the shaft (E). This shaft carries another small pulley (F), which drives a third large pulley (G). By this arrangement the speed of the final pulley (G) is reduced the same amount as if a single pulley four times as large had been placed on the shaft (B). This may be more easily understood if we consider that each of the small pulleys is one-half the size of the larger pulleys. Thus, if (A) revolves at 100 revolutions per minute (B) will

turn at 50 revolutions, and (C) at the same speed. The pulley (D) will then be turned at 25 revolutions per minute, and the pulley (F), turning at this speed, will drive pulley (G) at 12-1/2 revolutions per minute. If the pulley (A), turning at 100 revolutions, was connected directly to a pulley large enough to reduce its speed to 12-1/2 revolutions, the latter would have to be eight times the size of (A) or four times the size of (B).

Wherever a shaft turns, a pulley carries a belt, or any two surfaces move upon each other there is friction, and wherever there is friction there is loss of power. For this reason the less shafting, the fewer pulleys, and the more direct the transmission of power the better. In planning or setting up a stationary motor to drive machinery of any kind you should bear this in mind, and should aim to carry your power as directly as possible and to avoid all shafts, bearings, pulleys, etc., not absolutely necessary.

A single long shaft carrying a number of pulleys will produce far less friction and will have less loss of power than a number of small shafts, each of which carries but one or two pulleys. Broad, heavy belts will transmit more power running slack than light, narrow belts, which will slip unless they are very tight, and a tight belt increases the friction, but a belt should never be slack enough to slap and jump, as a slapping belt uses up a lot of power and is always liable to come off the pulleys.

In a great many cases plain manila rope and grooved pulleys will work better than regular belts and flat pulleys, especially where the power is transmitted for long distances. Leather belting is the best kind, but where the machines are exposed to dampness, rubber or woven web belts are better.

Great care should be taken to line up all shafts and

pulleys so they run true and are parallel. A shaft or pulley out of line with the one it is driving will cause lots of trouble. By measuring the distance from each end of a shaft to the corresponding ends of the other shaft you can determine when they are parallel, and by placing a string along the edges of the pulleys and squaring it with the shafts you can easily get everything lined up (Fig. 8). Shafts are usually carried in bearings or on brackets or supports known as *hangers*, and most of these are provided with adjusting nuts by which the shafts may be lined up to a certain extent. In some places a hanger cannot be used, and in such situations devices called *pillow-blocks* are used. Hangers and pillow-blocks have oil-holes or grease-cups for lubrication, and care should be taken to have these on the upper side of the bearing when they are designed for oil, or where they can be readily reached when grease-cups are provided.

A great many machines are *not* operated all the time, but must be stopped when adjusting or starting the work or frequently stopped and started while in operation. To avoid the trouble and delay of stopping the motor each time a device known as a *tight-and-loose pulley* is used. This affair (Fig. 9) consists of two pulleys of the same diameter placed side by side on a shaft, one of the pulleys being loose and moving freely on the shaft while the other is attached firmly and moves with the shaft. By means of two fingers, one on either edge of the belt, the latter may be slipped sideways from one pulley to the other. When the belt is on the loose pulley no power or movement is transmitted to the shaft, but when it is shifted to the tight pulley the shaft is turned and the machine operates. Sometimes these tight-and-loose pulleys are placed on the driving-shaft, and at other times on the machine itself. In many cases they are arranged on a small independent shaft near

the machine, and this is known as a countershaft. In setting up a tight-and-loose pulley it should be placed so that the belt is not too tight, or it will be difficult to shift easily; and the shifting device should act upon the driving side of the belt, and not on the return or idle side.

Sometimes a machine runs in the opposite direction from the main shaft or motor or is at right angles to the other machines. In such cases the motion may be reversed or turned at right angles very easily. By taking a half turn or twist in the belt, as shown in Fig. 10 A, the driven pulley

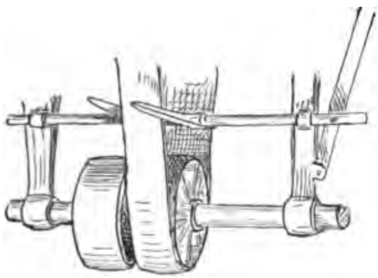


Fig. 9

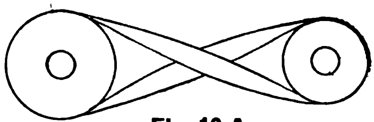


Fig. 10 A

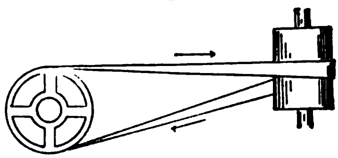


Fig. 10 B

runs in the opposite direction to the driver, as shown by the arrows, but in making this twist you should take care that the belt has enough slack to let it run smoothly and easily, for if it rubs where the two sides cross there will be a great deal of friction and the belt will rapidly wear out. When one shaft is at right angles to another the motion may be transmitted by a quarter-turn of the belt (Fig. 10 B), and the motion may be altered from right to left, or *vice versa*, according to whether the turn in the belt is right or left handed.

Where belts are carried for long distances they will sag badly from their own weight and are liable to slap up and

down and throw themselves from the pulleys. To avoid this guides or tighteners are used. The guides may be simply strong pins or rods with rollers placed on either side of the belt (Fig. 11, A), or they may be grooved or flat pulleys over which the belt is carried (Fig. 11, B). Similar guides are used where a belt turns a corner or is carried at an angle (Fig. 11, C). Belt-tighteners, on the other hand, must be forced or held against the belt with sufficient force to keep it tight. This may be accomplished by either weights or springs (Fig. 11, D), springs often being used on small or light belts and weights on long or heavy belts. Sometimes the distance between two shafts is very short and a direct belt would be impossible. When such an occasion arises the belt from one shaft may be carried around an idle pulley and back to the other shaft (Fig. 11, E). Or, if the pulley (A) is fastened to a shaft it may be used to transmit motion in another direction. Another method of using a short belt is illustrated in Fig. 11, F, in which the belt is held tightly against the pulleys by idlers (A, A). In one case the idler

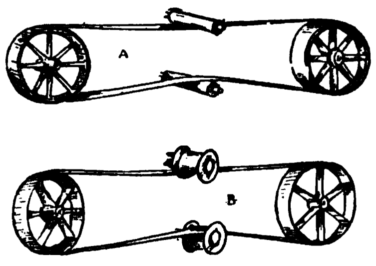


Fig. 11

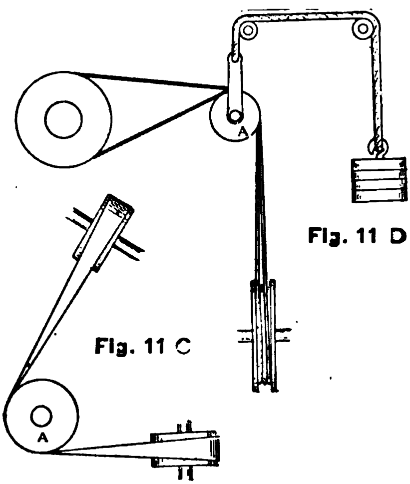


Fig. 11 D

Fig. 11 C

merely holds the belt tight by its weight, while in the other diagram it holds the belt tight and also aids in transmitting power by its friction on the two pulleys. In either case the idler should be placed against the *return* side of the belt, and not on the driving side.

Belts are fastened together in various ways, but metal fasteners or lacings are the best methods. On small belts plain metal hooks (Fig. 12, A) will serve very well, and the so-called *alligator fasteners* (Fig. 12, B) will hold a very large or heavy belt securely.

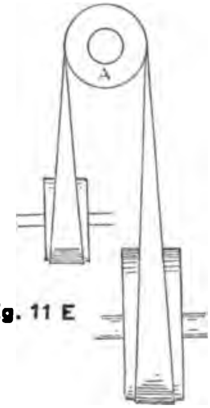


Fig. 11 E

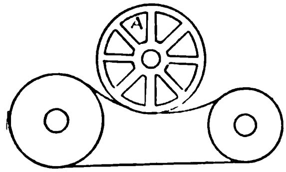
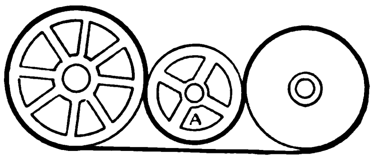


Fig. 11 F



Most belts, however, are laced together with rawhide strips or belt-lacings. There are various methods of lacing a belt, but the object is to make a firm, pliable joint, with the smooth portion of the lacings next to the pulleys. Several forms of belt-lacing are shown in Fig. 13. In lacing a belt *always* use a punch for making the holes; a hole made with an awl, knife, or other sharp-edged tool will always tear out. If the belt is slipped from the pulleys when being laced it may be drawn as tight as desired, but a better plan is to hold the belt at the desired tension and lace the ends while clamped in a belt-stretching device (Fig. 14). Such

affairs may be purchased ready-made, but any boy can make one in a short time.

Installing Stationary Motors

The installation of a stationary motor is not essentially different from that of a marine engine, but is much easier and simpler.

There is usually plenty of room for placing the motor and making connections, and you can arrange a shelf for the

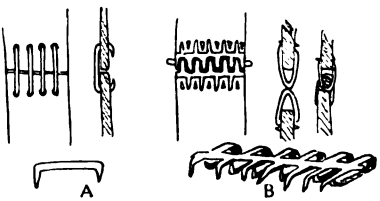


Fig. 12

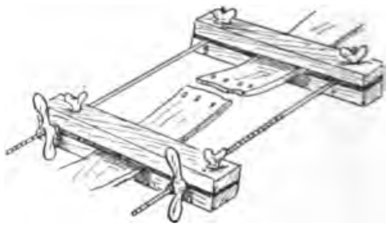


Fig. 14

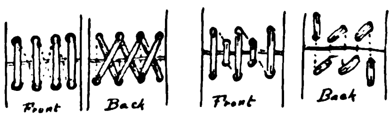


Fig. 13

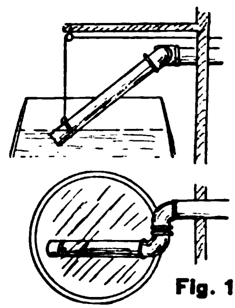


Fig. 15

fuel-tank, for batteries, etc. In connecting the fuel-pipes, water-pipes, and exhaust you should use the same care as in marine-engine work, although there is little danger of short-circuited wires if the motor is set up under cover. The exhaust should be free from sharp turns and corners, it should be of ample size, and some sort of a muffler should

be used. Any good muffler will work on a stationary motor as well as on a marine or vehicle motor, but the exhaust may be readily silenced by much simpler and cheaper methods.

If the exhaust is led into a pit in the ground and the hole covered with heavy boards or a slab of iron or stone on which sod or earth is piled the sound will be completely muffled, but a small vent should be left to allow the gases to escape, and care should be taken that the pit will not become filled with water during rainy weather. Another way is to bury a large earthen or tile pipe in the ground and run the exhaust into this.

A very effectual silencer can be made by using a barrel, keg, or hogshead partly filled with water. By arranging the extreme end of the exhaust-pipe so that it may be raised or lowered the motor may be readily started with the exhaust opening above the water, and after it is running the exhaust may be lowered into the water. Fig. 15 shows how this may be accomplished.

Never lead an exhaust into a chimney, water or steam pipe, smoke-stack, or similar inclosed spaces; unburned gases may enter and later explode with serious results. Even if this does not occur, the gases from the exhaust will soon ruin the pipes or mortar.

The mufflers and exhaust-pipes on stationary engines become very hot, and should always be covered with asbestos. If this is not done you are liable to be severely burned, or clothing or other objects may be ignited if they come in contact with the pipes. Exhaust-pipes, where they pass through a wooden wall or partition, should be protected by asbestos or tile and a metal collar should be placed over the hole in the wood with an air space of at least one inch between the wood and the pipe.

The bed for a stationary engine is very important. If the

engine is light the bed must be firm and the motor well bolted to it to overcome vibration and the weight of belts and other devices operated by the motor. If the engine is very heavy its own weight may be sufficient to hold it in position, but, nevertheless, a bed and secure fastenings should be furnished.

The bed for a stationary motor may be constructed of brick, stone, cement, or timbers, and the material used depends a great deal upon the space at hand, the location, the size of the motor, and the amount that you can afford to pay for the foundation. The most satisfactory beds are made of solid concrete, with timbers embedded just far enough apart for the base of the motor to be bolted to them (Fig. 16, A). The timbers should be large and strong, and to hold them immovably in the concrete, spikes or bolts should be driven into them before they are placed in the concrete.

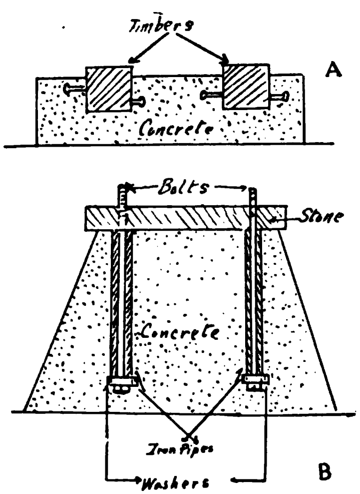


Fig. 16

The cement foundation and the timbers should be smooth and level, but there may be a depressed or hollowed space under and around the motor to catch any oil or water, and drains should be led from this space to a sewer or drain pipe.

In placing the motor you should see that it is so located that any or all portions of it can be readily inspected, cleaned, or repaired. The motor may be bolted to the timbers by lag-screws screwed down through the holes in

the engine-base, or bolts may be placed in the timbers before they are embedded, the engine set over these, and the base secured by nuts screwed on the bolts. Washers should always be placed between the heads of the lag-screws and the base of the motor or between the latter and the nuts. The nuts or lag-screws should be tightened slowly, first at one corner, then at another. If one bolt or nut is fully tightened up before another an unequal strain may result and the bed-plate may be cracked or broken. If, when setting up on the nuts, you find that there are any inequalities in the timbers or that they are not exactly level, you may correct the fault by placing thin shims of wood or metal underneath the motor-base.

For very large motors the beds may be constructed of solid concrete or of bricks set in concrete, and on top of this a flat slab of flagstone or granite should be placed. Such a bed should be carried well down into the earth below the frost-line, or if on the second floor of a building solid iron columns or strong supporting-timbers should run from the base to a firm foundation in the earth. The sides of these heavy beds should slope out a little, and the bolts for securing the motor should be immovably set into the concrete. An excellent method is to insert the bolts through iron pipe with a nut and washer at the lower extremity and embed the whole affair in the cement (Fig. 16, B).

When a wooden bed is desired it should be strongly mortised and bolted together and firmly fastened to the floor or ground. When motors are on floors above-ground they should be placed as near the side or one corner of the building as possible, and the floor under and near the motor should be very firmly and rigidly braced. Most floors are too light to support even a small motor without extra bracing, and if the motor jumps or vibrates even a little it will shake and

jar the entire floor and will soon loosen the fastenings besides rendering it very difficult to operate the other machines properly. · A good bed should be strong and steady enough to hold the motor immovable even under its heaviest work and highest speed.

A great many small stationary motors are sold already mounted on skids or frames so they can be readily moved from place to place, while others are mounted on light trucks or wagons (Fig. 17). For light work, or where

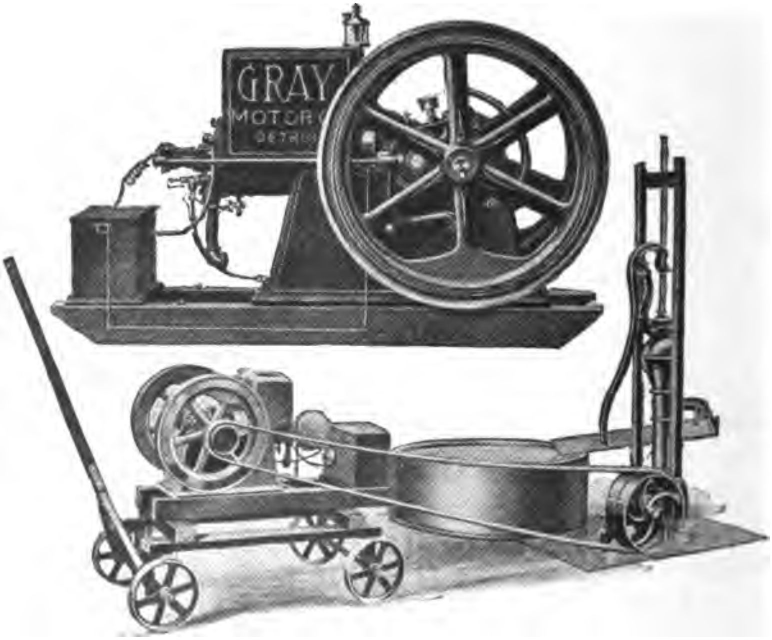


Fig. 17

directly connected to machinery, as in the case of vacuum cleaners, pumps, and agricultural machines, this system answers very well, but it is not advisable where a motor is used to run machines in a shop or factory.

If you have a motor-boat you can easily use the engine for stationary work in the house or shop during the winter months when your boat is pulled up. If care is used this will not injure the motor, and, in fact, it will be in far better condition than if left in the boat through the winter. For operating buzz-saws, cream-separators, pumps, grindstones, and many other purposes the marine motor will not require a governor, but if used for lathes, sewing-machines, or any device requiring a steady speed and frequent interruptions a governor must be rigged up.

A very serviceable and economical stationary motor may be obtained from an old discarded automobile. If the engine, clutch, and transmission are in serviceable shape the wheels, body, and other parts may be removed and the frame supported on a timber foundation. By attaching a pulley to the rear axle the old vehicle may be made to run a lot of machinery. You must remember that the two halves of an automobile axle are separated by a *differential*, and that either one can turn readily without moving the other. If your pulley is connected to a machine and the other side of the axle is free the pulley side will stand still and the free side revolve when the motor is running. To avoid this the end of the axle not used for a pulley should be fastened so it cannot revolve. The wheel of the auto with the tire removed will serve very well for a pulley, and many people run farm and shop machinery with their automobiles. It is a very easy matter to jack up a car, place firm blocking under one end of the rear axle, chock the other wheel and the front wheels so they cannot move, and run a belt from the rim of the free wheel to the machinery you wish to drive.

Even a motor-cycle can be used in this way to advantage, and you will be surprised to find how much machinery a very small gasoline motor will drive.

A motor-cycle or a very small marine engine of 1-1/2 to 2 horse-power will easily run a grinder, a good-sized lathe, a circular saw, a pump, and other light machinery, and by its use you can accomplish ten times the amount of work that you could do by hand.

Two Boys and a Motor

(By One of the Boys)

"Tom owned the boat, but as he did not care about machinery and never seemed to be able to fix the engine when it went wrong, we always went out together, and we felt as if the boat belonged to us equally. Last fall, during a big storm, the boat broke her painter and was thrown upon the rocks and smashed. The boat was ruined, and we were almost heartbroken over it, for we had both counted on taking a cruise in her next summer, and were very fond of the little craft. As the motor and other fittings were not injured, we took them all out, as we thought that perhaps we could use them for another boat if we could manage to get hold of a good hull. We carried the motor, the shaft and propeller, the tank and all the pipes, etc., up to our woodshed in wheelbarrows, and I took the motor apart and cleaned and oiled it so it would not rust.

"Our summer home did not have any running water, and all the supply came from a big tank on a tower where it was pumped by a windmill. The same storm that broke up the boat also blew the windmill to pieces, and we had to pump the water up by hand. This was hard, slow work, and one day while I was pumping up the water it suddenly occurred to me that I could make the motor from the boat do the work just as well as the windmill.

"The pump was connected to the windmill by a long rod

which could be disconnected when we used the pump by hand, and I couldn't figure out just how I could connect the motor at first.

"Anyway, the first thing to be done was to set up the motor and get it running. Tom and I were quite enthusiastic about the new scheme and at once set to work to get the engine ready.

"We first had to make a bed, and, as the woodshed floor was not very steady or strong, we decided to make a bed right on the ground. To do this we cut away a piece of the floor near one corner and drove four big stout posts into the ground about three feet apart each way. We then sawed off the tops of these close to the floor and made a frame of 3 x 4 scantling, which we nailed and bolted to the four posts. Over this we nailed two-inch planks, and on top of these we bolted two 3 x 4 timbers edge-up for the motor-bed. We screwed the motor onto these with lag-screws, and on the wall near the motor we built a shelf and fastened the gasoline-tank. We put a box for the batteries on this shelf also, and then had to make some arrangement for cooling the motor with water. Tom suggested that we could use water from the pump and let the motor pump it for its use, but I said that the motor would get too hot before the water began to pump from the deep well. We then decided to put up a tank for the cooling water, and we got an old oil-barrel and set it up near the motor. We ran the intake-pipe from the pump on the motor to the bottom of the barrel, and from the outlet we ran a piece of old hose so that it projected over the upper edge. We were now ready to try the motor, and after filling the barrel with water and getting everything ready we started it up. The motor started right off, but it ran so fast that we had to shut it off, but it didn't jump or shake the bed very much, so we

felt sure the bed was firm enough. Tom thought we could never manage it, but I told him as soon as we put the motor to work that it would run slow and steady enough, and reminded him of how the motor used to race in the boat if we started it when the boat was out of water.

"The pump to the well was outside the woodshed, about ten feet from one end, and I decided we would have to run a shaft out to it and connect the pump to some sort of a crank on the shaft.

"As the old windmill was no good, we got this down and took it apart, as I thought we could arrange the crank on this for the motor to run. The windmill moved the pump-rod up and down by some gear-wheels and a wheel with a pin in it, and after a lot of trouble trying to get this machinery apart Tom said he thought we might fasten the whole affair right over the pump and connect it to the motor. This seemed a good idea, so we built a sort of frame above the pump and got the blacksmith in the village to make a short rod like the long one that was on the windmill. We connected this to the windmill wheel with the pin, and when we turned the latter by hand we found it moved the pump up and down all right. One end of the axle of the windmill had a flange on it to which the windmill had been fastened, and we decided to make this into a pulley to run the pump. We puzzled a good deal over making this pulley, but we finally arranged it by fastening two pieces of two-inch plank to the flange and sawed and planed off the corners until it was round and the same size as the flange. We now had to arrange a pulley on the engine, and this we bought of the blacksmith, who kept a lot of old junk and odds and ends on hand. The blacksmith was an awfully pleasant fellow and knew a lot about machinery, and when he found out what we were up to he said he'd come over and help us.

When he saw the pulley on the old windmill shaft he laughed and told us we could never pump the water that way. He said the pulley was too small and that if we wanted to get power enough out of the engine to work the pump we would have to use a big pulley on the shaft and run a belt from a small pulley, and he explained that in this way the big pulley would run slowly but would have a lot of power, while with the small pulley there wouldn't be any power, but the pulley would run fast if it didn't have much work to do.

"This kind of discouraged us at first, but he said he had some big wheels that came off an old dumbwaiter and he could fix one of these onto the shaft of the mill, and that we could use a rope for a belt, which would be much cheaper than real belting and would work just as well. He also told us that we would have to use a tight-and-loose pulley on the motor or else on a separate shaft in order to start the motor, for he said we wouldn't be able to turn it over by the fly-wheel when the pulleys and shafts were connected. This stumped us at first, for we didn't want to spend our money that we were saving up to get a new boat, but he said it would be easy enough to rig up a tight-and-loose pulley out of odds and ends, and told us to come over to his shop on Saturday. When we went over there he had found a couple of small pulley-wheels and an old well-wheel, and he said these would be all right. First he fastened the well-wheel on the end of a piece of iron shaft about three feet long, and then he fastened a sort of collar or ring tight to the shaft a short distance from it. Then he slipped one of the small pulleys over the shaft so that it fitted snug, but turned easily, and then he fastened the other one up close to it and screwed it to the shaft so it couldn't turn. The next thing he said was to make some *hangers*. He didn't have any old iron hangers on hand, but he said that wooden ones

would do just as well for our 'shop,' and told us how we could make them by fastening up timbers with a hole in them for the shaft. We took the shaft and pulleys to the wood-shed and worked the rest of the afternoon making the hangers. These were just pieces of hard wood which we bolted onto a beam over the motor and braced with pieces of scantling from each side. When we got ready to put up the shaft we tied a string around the pulley on the motor and carried this up to the pulley on the shaft and moved the shaft about until the pulley was right in line with the one on the motor. Then we fastened up the hangers and were ready to connect the motor to the pulley with a belt and to make a rope to run out to the wheel over the pump.

"Of course we had forgotten all about the position of the pump outside while we were so busy inside, and after we had finished the hangers and started to cut a hole in the wall for the rope we found that the wheel on the pump was away off to one side at a different angle from the grooved pulley on the shaft inside. We couldn't think how to fix this, for we could not move the wheel on the pump, and if we moved the one on the inside shaft the other pulleys would be out of line on the motor. It looked as if we would have to move the motor and all, but Tom said we'd better ask the blacksmith first. When he heard about it he came right over, and when he saw the trouble he said, 'Why, that's easy; all you've got to do is to carry the rope around an idler.' Then he showed us how we could put a piece of rod with a loose pipe on it near the pump-pulley and could let the rope run around this so that it led straight from this idler to the pump-wheel on one end and to the pulley inside the shed on the other.

"We got a long piece of good strong manila rope and stretched it from one pulley around the other one and back,

and Tom, who could splice, fastened the two ends together. We next got a piece of belt and fitted it to the pulley on the motor around the overhead shaft, and, as everything was ready, we started up the motor. At first it ran awfully fast, but I jumped up and pushed the belt from the loose pulley over onto the tight one and the engine slowed right down, the shaft began to turn, and we heard the pump outside begin to clank just as it used to do when the windmill was working. We ran outside, and, sure enough, the pump was going up and down and working as nice as could be. We were tickled most to death and ran up to the house and had mother and father come out to see it. They were greatly interested, and father said that he thought we deserved encouragement in our mechanical work and that as long as we had the engine doing this work we might as well let it do something else, too. A few days later he bought a circular saw, and after we connected this to the motor we found it lots of fun to saw up all the old driftwood and stuff that came ashore. Father had always paid a man to chop this up, and he said that if we would saw the wood he would pay us instead of the man. One of Tom's friends had a turning-lathe, and when he saw how our motor ran the pump and the saw he brought over the lathe and connected that to the motor. Then we brought the grindstone into the shed and ran that by the motor, and all the neighbors brought over their tools, axes, etc., and we made quite a lot of money by doing this sort of work and by sawing their wood. Before very long our 'shop' became quite famous, and when we had to go back to school for the winter we felt dreadfully sorry to have to leave our motor and machinery.

"Tom liked the shop so much that he said he thought he would keep the motor for that purpose and would get along without a motor-boat next year, but as it turned out we are

going to have both the shop and the motor-boat also. At Christmas time father told us that as long as he would have been obliged to buy a new windmill and our motor did the work just as well and had saved him that expense, he would give us the money for a motor-boat instead, and so we are going to the motor-boat show in the spring and are going to buy a new boat and expect to have lots of fun with our boat and our shop next season."

Part IV

THE VEHICLE MOTOR

Chapter XI

AUTOMOBILES AND THEIR MOTORS

THE modern automobile is a wonderful vehicle, and combines the highest art and most exacting work of a variety of trades. By gradual development it has become a complicated and intricate machine, equipped with every known device for comfort, luxury, and ease, each and every one of which adds its quota to the multiplicity of wires, tubes, rods, and other parts.

Nevertheless, the all-important part of any automobile is the motor, for without a strong, reliable, and efficient engine the most beautifully finished and luxuriously equipped car will be practically worthless.

Stripped of its body, fenders, and accessories, the most complicated and up-to-date car becomes comparatively simple, and resolves itself into the motor, with its attachments and fittings, the frame or chassis, the clutch and transmission gears, the wheels and axles, the steering-gear, and the brakes. All other parts are merely accessory and have nothing to do with the actual speed, power, reliability, efficiency, or operation of the motor-car.

A stripped automobile with a soap-box for a seat will run just as well as the complete machine with its beautiful paint, its rich upholstery, its foot-warmers, lamps, mirrors, and other fittings.

All too often this fact is overlooked, and the prospective

purchaser of an automobile judges the machine by its external appearance, the depth of the cushions, the finish of the paint, or the completeness of the furnishings.

Many a poor, cheap, or inefficient motor is hidden beneath the gleaming paint and brasswork of a car costing several thousand dollars, while some old, out-of-date car with scratched paint and worn cushions may have a clean, smooth-running, powerful motor that will carry the car uphill and down across the country for hour after hour with never a miss or a moment's delay or trouble.

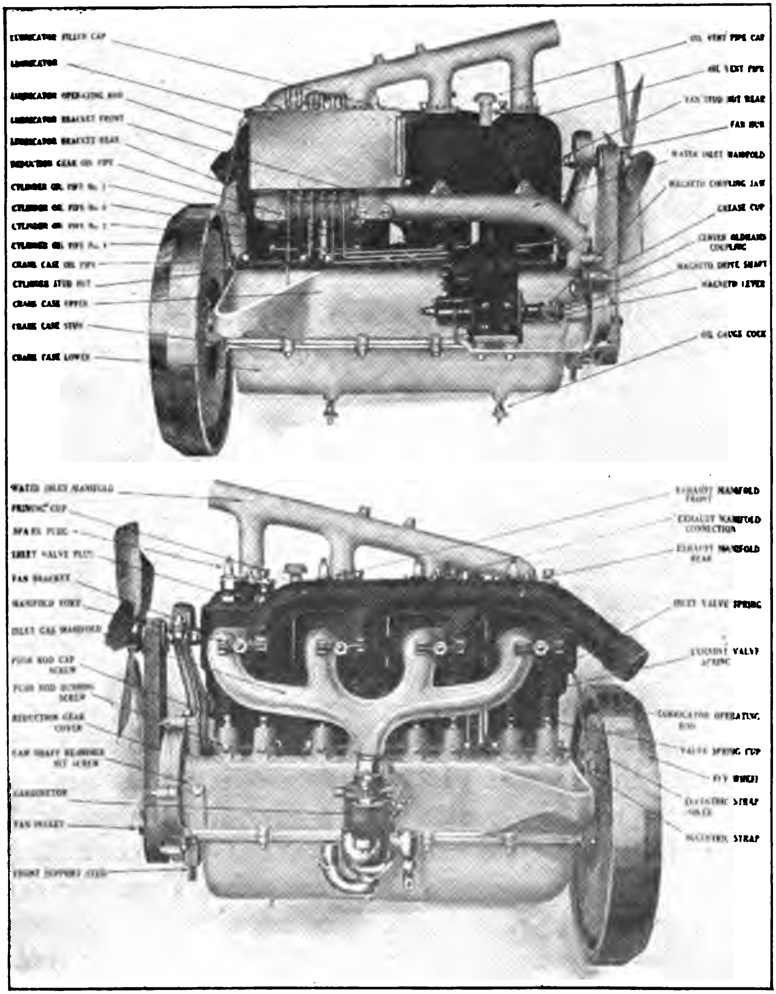
Most cars have good motors installed when they are built, but it is just as easy to ruin the motor of an expensive car as of a cheap one if neglected, uncared for, and abused.

Automobile Motors

The automobile motor of the present day is usually a four or six cylinder engine of vertical form, and the majority of them are of the four-cycle type. The earliest designs were single-cylinder cars, or, as commonly called, *one-lungers*, or else they had two-cylinder opposed motors. The demand for speed and power and the increase in size and weight of the cars soon brought about the adoption of four-cylinder motors, and later many of these were succeeded by six-cylinder motors on account of their smooth-running, silent, and powerful action.

A great many trucks and commercial vehicles still use two-cylinder motors; several makes of cars have adopted three-cylinder two-cycle engines, and not a few of the old one-lungers still perform excellent service day after day.

In these old single-cylinder machines as well as in the majority of two-cylinder cars the cylinders are horizontal, but in later designs the cylinders are usually vertical; and, as



PARTS OF AN AUTOMOBILE MOTOR

practically all the pleasure cars now made or in common use have this type of motor, it is scarcely worth while considering the others.

Automobile motors may be either of the two or four cycle type, and they may be equipped with either air or water cooling systems. The majority are, however, four-cycle and there are far more water-cooled than air-cooled cars. Most automobile motors are of the poppet-valve type, but quite a number are sleeve-valve engines, while a few are motors with rotary valves. Among automobile motors you may find various valve arrangements. Probably the larger number are L-head or T-head forms, but a great many have overhead valves, while still others have a combination with one valve in the side and the other overhead.

The principle, operation, construction, and general care of any automobile motor is practically the same as for any other motor of the same type.

The only difference between the motor of a motor-car and a similar design for marine or stationary use is in the minor details, attachments, and accessories which have been designed to adapt it to automobile work.

The engine of a motor-car appears at first sight more complicated than a similar motor in a boat, but this is more apparent than actual. In an automobile a great deal of machinery must be packed into a very small space, and, moreover, the throttle, timer, and various other controlling devices must be operated from the driver's seat or the steering-column. As a result there are a number of rods, arms, springs, etc., which are not required on other types of motors, and all the wires, pipes, and attachments are so closely placed that it is difficult to grasp their meaning or trace them from place to place at first sight.

In taking down, repairing, or overhauling an automobile

motor the work is accomplished precisely as with any other form. The presence of a radiator and fan and, perhaps, *self-starting* devices may complicate matters somewhat, but these are things entirely apart from the motor proper. The radiator is easily disconnected and taken off, the fan is so simple that it is of no moment, and no one but an expert should ever attempt to repair or overhaul any of the electrical or air-driven self-starting devices.

Automobile Ignition

The majority of automobiles are provided with both magnetos and batteries for ignition purposes. Some cars use magnetos alone, but only cars of old design use batteries without a magneto.

The magneto may be of the direct-current, low-tension type in which the primary current generated is sent through a coil, or it may be of a high-tension alternating type without a coil.

Some engines have the same coil for both battery and magneto current, while others use two distinct coils. A great many motors have an ordinary timer and vibrating-coil for the battery current, and either a high-tension magneto without a coil or a low-tension machine with a separate coil in addition. Sometimes only one set of spark-plugs is furnished for both the magneto and battery current, but most automobile motors have two distinct sets, one for the magneto and the other set for the battery current.

In fact, practically every different make or model is equipped with a distinct ignition system or devices, and, as the number is very great, it is impossible to describe and explain them all. The majority of cars are provided with well-known and standard types of magnetos and easily

understood systems, and if these are once mastered any other form will be very easy to understand, adjust, or repair.

As the principal troubles with all motors arise from faulty or deranged ignition, this is a most important matter, and every owner, operator, or user of a motor or motor-vehicle should become thoroughly familiar with its ignition system and should be able to locate any ignition trouble very quickly.

Magnetos, as explained in a previous chapter, are broadly divided into two classes—low-tension and high-tension. The true low-tension magneto is operated by a belt, gear, or friction, and produces a direct low-tension current, exactly like that of a battery, and the current generated is passed through a timer and coil precisely as is an ordinary battery current. Such magnetos operate at high speed and are equipped with governors, which prevent their operation at excessive speeds. Their revolution has no direct relation to the speed of the motor, as the proper time for making the spark is controlled by a timer separate from the magneto. This class of magnetos is used on a great many marine engines and stationary motors, but in automobiles they are mainly utilized for producing a lighting current for lamps, for charging storage batteries, or for ignition on motors which were originally equipped with batteries only.

Other so-called low-tension magnetos produce a primary current which is passed through a coil and thence back to the magneto, where it is distributed to the proper wires. In many of these magnetos the breaker of the magneto acts as a timer for both the battery and magneto currents.

In true high-tension magnetos the production of the primary current and its transformation to the secondary current occurs within the instrument itself, and no outside coil is used, and but one primary wire is necessary. This

wire leads to the switch, and from the switch to the ground, and this is merely used for short-circuiting or stopping the motor. With this class of magnetos batteries are seldom used, and the motor is started and operated entirely on the magneto.

The driving mechanism of a magneto, except of the friction-driven type, is important, for if there is any play or looseness or any appreciable variation in the accuracy of its action the timing of the sparks may be greatly altered and the motor may miss or behave poorly.

Aside from the connection of the driving-shaft and the wires there are really but two parts of a magneto which will require attention or which, should there be trouble, it is wise for an amateur to meddle with. These two parts are the *distributer* and *breaker*. The breaker is a small mechanical

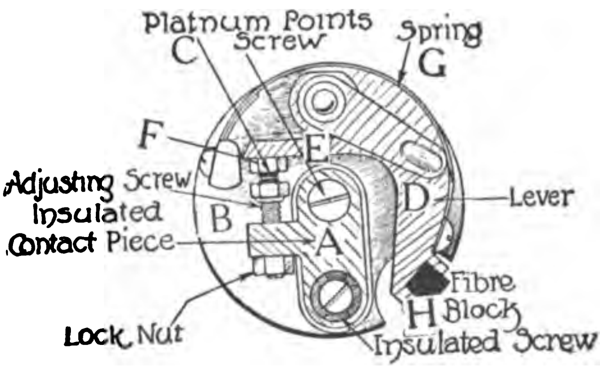


Fig. 1

device inclosed in a case called a *breaker-box* and corresponds in its action and functions to an ordinary timer. In a way all breakers are more or less alike and consist of a point connected with one primary wire which strikes another point connected with the other primary wire or the ground.

In minor details each make of magneto has a breaker slightly different from others, but these differences are merely in the arrangement of cams, springs, levers, etc.

Breaker Adjustments

A magneto which is very widely used on all types of gas motors is the *Bosch*. The breaker-box of this magneto is shown in Fig. 1, and consists of an insulated piece (A) to which is attached the adjusting-screw (B), with a platinum point (C). Near this piece is a lever (D) with an arm (E), to which another platinum point (F) is attached so that it bears upon the point (C) by the pressure of the spring (G). At the other extremity of the lever is a block of fiber (H) which presses upon a projection outside of the mechanism as the magneto shaft revolves. This is so placed that when the motor is in the firing position for a cylinder the moving projection presses upon the fiber block and breaks the contact of the platinum points, thus interrupting the current and causing a spark at the plugs.

A different arrangement is used in the Remy, Splitdorf, Connecticut, Mea, National, Eiseman, and other magnetos, some of which are shown in Fig. 2. In these breakers the platinum points are separated and the current broken by the action of a cam on the armature shaft pressing on a lever which is held in position by a spring.

As the size and intensity of the spark, as well as the exact time at which it occurs, is regulated largely by the moment of breaking and the amount of the separation of the contacts, it is very important that the proper adjustment of the breaker-box is made and maintained. In nearly all magnetos the cover of the breaker-box may be readily removed and the contact-points may be adjusted by means of screws and

lock-nuts (Fig. 1), but in the Remy magneto (Fig. 2, A) the adjustment may be made from the outside of the breaker-box while the motor is in operation.

In addition to their proper adjustment the contact-points should be kept smooth and clean. This may be accomplished

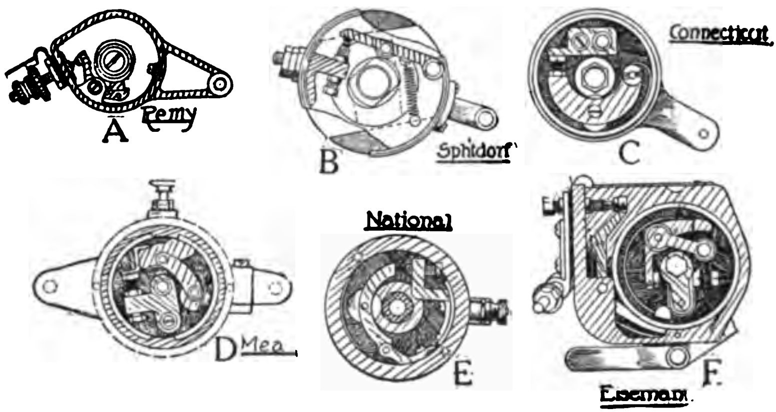


Fig. 2

by the use of a fine file and by now and then readjusting the points and removing all fine dust and dirt with a soft brush. Most magneto-manufacturers furnish a small wrench to fit the adjusting-nuts and a thin metal gage for determining the distance between the contact-points. Oil should never be placed in the breaker-box if it is equipped with fiber, but some makes require a little oil from time to time. The maker's directions usually designate how and where the oil should be used.

The other important part of the magneto which may require your attention is the *distributer*. This consists of a device much like an ordinary timer, and usually includes a rotating arm or disk which passes over brushes or points connected with the wires leading to the various spark-plugs.

In some forms, as, for example, the Remy (Fig. 3), the distributer is an arm (A) which passes over four segments (in four-cylinder motors) and which comes into contact with a segment just as the proper cylinder is in its firing-position. As there are as many segments or brushes in a distributer-box as there are cylinders to the motor, the arm or disk of the distributer moves at the same speed as the cam-shaft, or one-half as fast as the main magneto shaft and breaker.

Other distributers have carbon brushes in place of the segments, with a disk carrying a contact piece which rubs against the proper brushes in their turn. The cover to the distributer-box is easily removable, but in taking it off care should be used not to drop a brush or spring. Brushes are often a great source of trouble, for if the disk or contacts become rough or worn the brushes cut away rapidly and become either too short or else fill the case with dust and dirt, which interfere with the proper action of the distributer. In case a brush is worn or broken it should be replaced with a new one. Sometimes a brush will stick in its recess, owing to some derangement of the tiny spring behind it. When this occurs a thorough cleaning will often help a great deal, but a new spring is usually better.

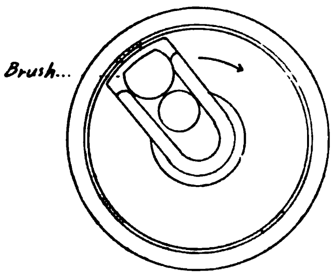
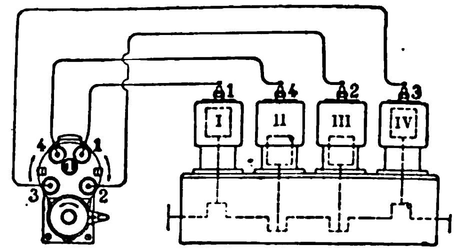


Fig. 3

As the proper amount of secondary current can only reach the plugs through the distributer, it is highly important that the mechanism should be kept clean and in good order. Magnetos sometimes run in one direction and sometimes in another, and in replacing or renewing wires it is important to know which way the magneto distributer turns. By

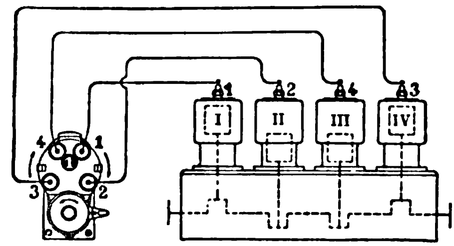
Magneto running clockwise
Firing Sequence
I, III, IV, II



View of Distributer End

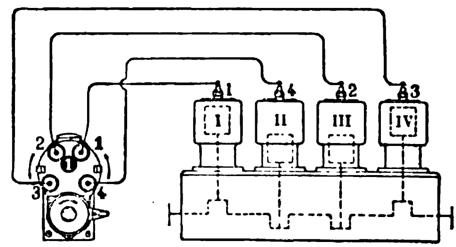
Fig 4 A

Magneto running clockwise
Firing Sequence
I, II, IV, III



View of Distributer End

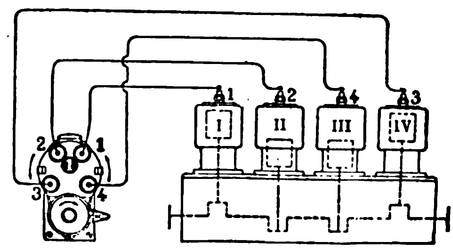
Magneto running anti-clockwise
Firing Sequence
I, III, IV, II



View of Distributer End

Fig. 4 B

Magneto running anti-clockwise
Firing Sequence
I, II, IV, III



View of Distributer End

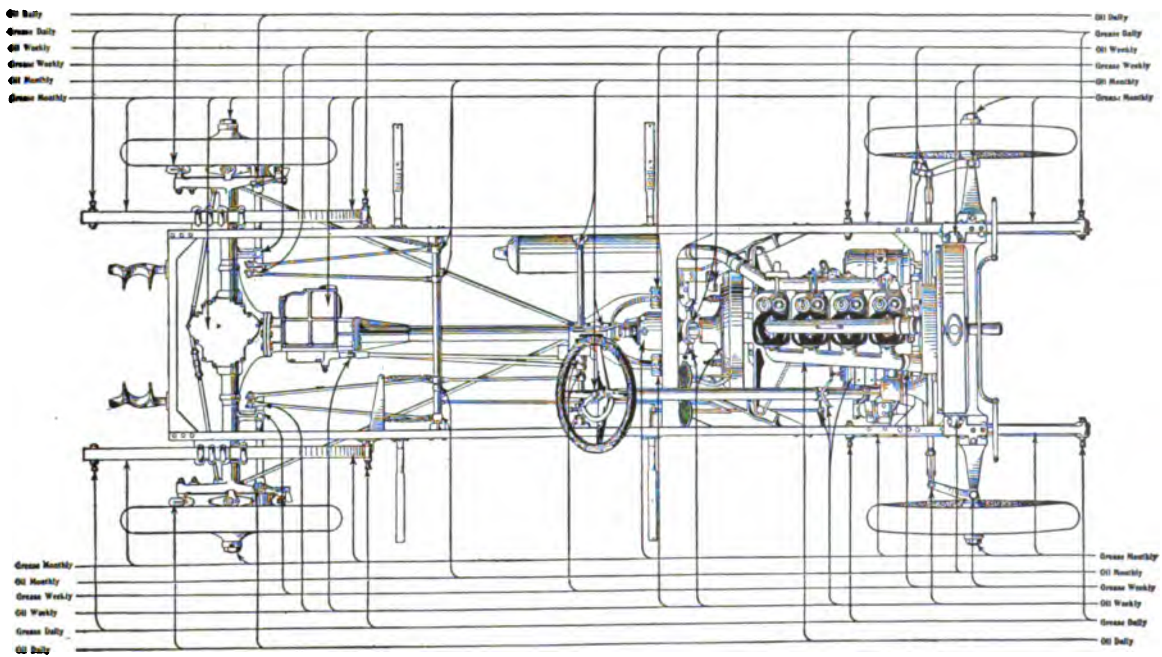
WIRES FOR FIRING 1, 3, 4, 2, RIGHT OR LEFT HAND ROTATION

turning the motor slowly and watching the magneto shaft you can readily determine its direction, and if the distributer is geared to the magneto armature shaft you will understand that it turns in the opposite direction. When replacing wires to the spark-plugs, and the terminals on the magneto are not marked, you should first ascertain which terminal is No. 1 cylinder. To do this turn the motor over slowly, with the distributer-box open, until on the firing-position in No. 1 cylinder. Then examine the distributer, and you will find the segment or brush in contact with the arm or revolving-disk. The terminal whose brush or segment is in contact will be the one to which you should connect No. 1 cylinder, unless the magneto has been changed while uncoupled or has been wrongly set.

The next terminal or brush in contact with the distributer-arm will be the next cylinder to fire, and hence the proper wire should be connected to it; thus, if the motor fires 1, 3, 4, 2 the plug wire of the third cylinder should be led to the next terminal after No. 1, etc. This is plainly shown in Fig. 4 A, in which the magneto distributer moves from right to left. If it moves in the opposite direction the wires would have to be altered, as shown in Fig. 4 B.

Locating Ignition Troubles

If your motor skips or misses fire it is very easy to determine if the fault is in the ignition, and, if so, which cylinder is missing. By using a screw-driver with a wooden handle each plug may be short-circuited in turn by placing the point or blade of the tool across the terminal of a plug and against the cylinder, or the metal part of the motor. If the plug thus touched is firing the motor will slow down and miss, but if the plug touched is not firing there will be no



WHERE TO OIL AN AUTOMOBILE

difference in the operation of the motor. When the missing cylinder is located rest the screw-driver against the terminal of the plug and keep the point a fraction of an inch from the cylinder. If a bright spark jumps across the gap you may be sure the trouble is in the plug itself, but if no spark occurs, or it is stringy, thin, pale blue, or weak the trouble will be found in the wires or magneto. By operating first on batteries and then on magneto you can determine which system is at fault and thus diminish the difficulty of locating it by one-half.

In searching for ignition troubles outside of the plugs go about it systematically. If the trouble is in the battery system first examine and test the batteries and look for loose connections, broken wires, or battery connections that rattle together. Next follow the wires to the timer, coil, switch, etc., and be sure there are none that are broken, rubbed, or loose. If you have a vibrator-coil, watch each vibrator-point, and while the motor is running on the batteries hold down each vibrator in turn. If all the vibrators are in proper order each cylinder will miss in turn as you hold down the corresponding vibrator, but if one is not operating properly the engine will not show any difference in its action when that vibrator is held.

Look for loose or corroded coil connections and then follow the wires from the coil to the magneto or to the plugs. If the trouble is in the magneto system, examine all wires and connections, then examine and clean distributer, and if the trouble is not remedied open the breaker-box and watch the spark at the breaker-points and alter the adjustment slightly.

There are so many wires in such a small space on an automobile motor that it is sometimes difficult to follow them. In many machines very little care is used in pro-

tecting the wires or keeping them orderly, and the result is frequent ignition troubles and difficulty in locating them.

The majority of modern cars now have special protectors, guards, or leads for carrying the various wires, especially the high-tension cables to the spark-plugs. These vary greatly in design, material, and arrangement, and a few of the best systems are shown in Fig. 5. The Packard and some other cars number the various leads, as well as the proper terminals of the magneto, and in this way a wire is easily and quickly traced. If your car does not have the various terminals and wires numbered you will save a vast amount of time and trouble by numbering them at once, but be sure you number them correctly; a wire or terminal with the wrong number is far worse than no number at all.

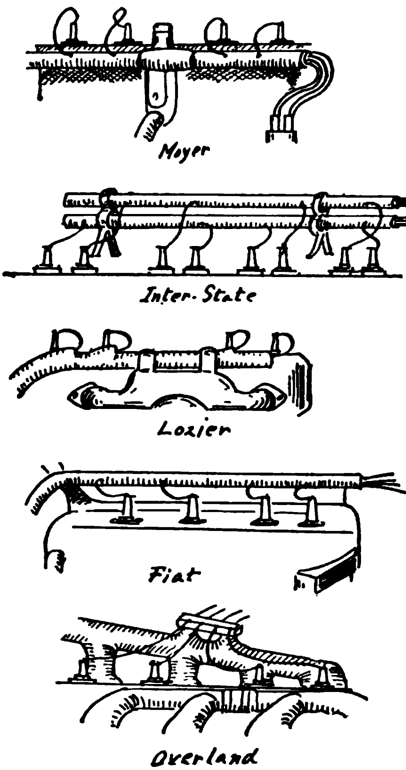


Fig. 5

Carbureters and Adjustments

There are a great many kinds of carbureters in use on motor-cars as well as on stationary and marine motors, but practically all now used are of the float-feed type and are more or less alike in their action.

Most carbureters are accompanied by full directions for adjustments and care, but it may often happen that the directions are not at hand or that you may have acquired the motor or car without any directions. Some makers use special carbureters of their own design or made especially for them, but the majority of carbureters in use are confined to a few leading makes. Among the most widely used are the Schebler, Stromberg, Rayfield, Kingston, etc.

There are various types or models of Schebler carbureters in use, and the method of adjustment varies more or less with each. In the original *Model D* form (Fig. 6 A) the adjustment is obtained by means of the air-valve (A) and needle-valve (B), but this model is not widely used on automobiles. The *Model L* is a later type, and is shown in Fig. 6 B. In this form there are several adjustments for varying speeds. To set this carbureter, screw in the low-speed valve (A) on the side of the carbureter until it is firmly seated, then loosen about one and one-half turns, prime or flood the carbureter, open throttle about two-thirds, retard spark, and start the motor. Next adjust the low-speed valve (A) slowly until the engine runs smoothly and evenly with throttle nearly closed. If it runs too slowly or stops with throttle closed, screw in on the throttle-adjusting-screw (B) until the proper speed is attained; if it runs too fast with closed throttle loosen out on the screw. Then, without touching the low-speed adjustment, move the pointer on the intermediate speed dial (C) until at No. 2. Open the throttle until the little roller below the dial is in line with it, advance the spark, and operate motor. If the motor backfires, move the pointer toward figure 3; and if too rich a mixture is being given, move it toward 1 until the motor runs well. Then open the throttle full and adjust the high-speed dial (D) in the same manner. If no satisfactory adjustment can be

obtained for any one of the various speeds a further alteration may be made by means of the air-valve thumb-screw (E). Loosening this is equivalent to giving less fuel, and closing it by screwing down on the nut is the same as giving more fuel.

The Schebler *Model O* (Fig. 6 C) has two jets of fuel, and in adjusting this form the two needle-valves (E, F) should

Fig. 6 A

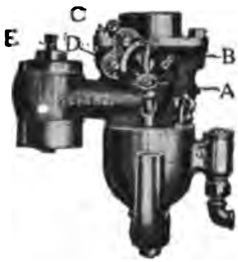


Fig. 6 B

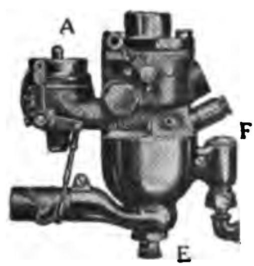


Fig. 6 C

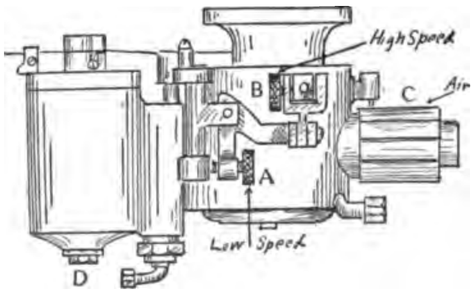


Fig. 6 D

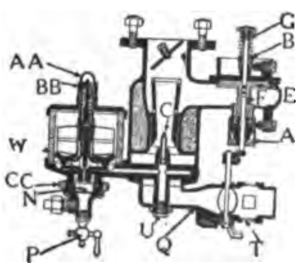


Fig. 6 E

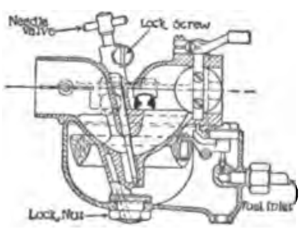


Fig. 6 F

be seated firmly with the air-valve (A) very lightly. Then turn the bottom valve (E) to the right until the motor runs smoothly when throttled down. Open the throttle about one-third, and if the motor backfires screw in the air-adjusting screw (A) until it ceases to do so; then open the throttle wide, and if the motor backfires at high speed turn the needle-valve (F) to the left until the motor runs evenly.

All the Schebler models are easily cleaned by removing the nut at the base of the bowl, and this should be done quite often if there is no strainer on the fuel-pipe.

The Rayfield carbureter (Fig. 6 D) is easy to adjust, but it is very different from that of the various Schebler models. The low-speed adjustment is first set by turning the low-speed screw (A) (the lower one on the carbureter) to the left until the arm above it just breaks its contact with the cam. Then turn it to the right about one and one-half turns, open the throttle about one-quarter, and start the motor. Shut down on the throttle until the motor idles slowly and smoothly, and gradually turn down on the low-speed screw, one notch at a time, until you are giving just as little fuel as possible without making the motor skip or stop. Then throw the throttle wide open, and if the engine backfires turn the high-speed nut (B) to the right until all the cylinders fire regularly. If the motor does *not* backfire when throttle is opened, turn the high-speed screw to the left until it backfires and then slowly to the right until it runs smoothly. In adjusting the high speed do not touch the adjustment for low speed, but if the motor backfires or misses at half or quarter speed open or close the automatic air-valve (C) slightly by turning to right or left as required. To clean the Rayfield remove the drain-plug (D) on bottom of the float-chamber.

The Stromberg carbureters (Fig. 6 E) are made in a num-

ber of models and styles, but they are all very easy to adjust. In these carbureters there are no needle-valve adjustments, the proper adjustment for both low and high speed being obtained by means of the air-valves. By turning the nut A up or down the low-speed adjustment is obtained, and by turning the nut B up or down the high-speed adjustment may be correctly made. For low speeds operate the motor with the throttle as nearly closed as possible and with the spark retarded. For high speed open the throttle and advance spark. Too much air makes a motor hard to start and causes backfiring; too little air makes the motor miss and is also indicated by the engine not picking up speed quickly and readily.

The Kingston carbureter (Fig. 6 F) is just the reverse of the Stromberg, inasmuch as it has no air adjustments and the only adjustment is the needle-valve. The adjustment is exceedingly simple, and consists in setting the needle-valve down until the motor backfires at slow speed and gradually loosening it until smooth operation is obtained. The motor is then speeded up with open throttle, and if it backfires the needle-valve is loosened a very little. The Kingston is cleaned by removing the plug in the base of the float-chamber, while the Stromberg has a drain-cock for the same purpose. It must be remembered that it is seldom possible to obtain a very satisfactory carbureter adjustment on a motor when running idle. After the best adjustment possible is thus obtained the car should be taken out on the road and tested on hills and on the level. The carbureter may then be altered to give the best results while pulling a load.

Chapter XII

CLUTCHES, TRANSMISSIONS, ETC.

THE engine of an automobile drives the car through a system of gears known as a *transmission*, which enables the operator to travel forward or to reverse at various speeds, or even to stand still while the motor is running.

There are various kinds of gears or transmissions known as *planetary*, *progressive*, and *selective*, and a few cars have no gears, but in their place a *friction-drive*.

The older types of cars, many light modern cars, and a great many commercial vehicles still use the planetary type, but the majority of cars are equipped with the selective type. The planetary gear (Fig. 1) consists of a series of

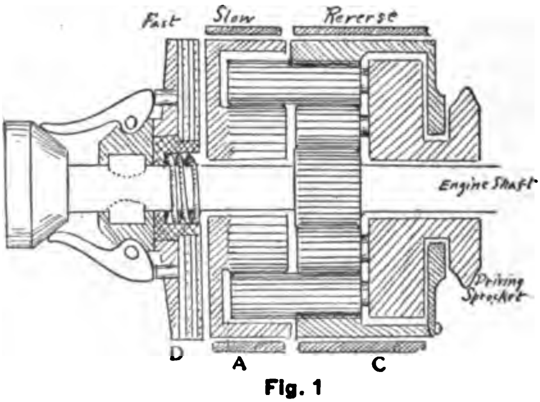


Fig. 1

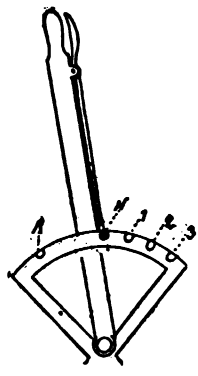


Fig. 2

pinions, internal gears, and friction-bands, as shown in the illustration, and, while the exact arrangement or the manner

of control may vary with different makes, yet the principle of all planetary gears is similar.

The planetary gear operates through the action of clutch or brake bands which prevent certain drums containing gears from revolving, and thus transmit the motion through the other gears. When the drum A is held by pressing forward on a lever or foot-pedal low speed is obtained. By releasing the drum A and pressing forward on the lever connected to C reverse motion is transmitted, and by releasing both A and C and throwing forward the lever connected to D the whole gear system is locked together and the motor drives the car direct without using the gears, and high speed is obtained. Some cars have the reverse and high-speed controls on one lever, others have low and high on one control, while others have three separate pedals as described.

Planetary gears are very simple, but they are noisy and require a good deal of attention. The principal sources of trouble are lack of grease and wear of the clutching-bands. As a rule it is seldom or never necessary for an amateur to take apart a gear, and if it is kept well filled with the proper grade of oil or grease and the brake-bands are adjusted or renewed from time to time no other attention is necessary.

The *progressive* and *selective* types appear far more complicated, but they are really very simple and easy to understand.

There are a great many patterns, kinds, and types of these gears in use, and it is not possible to describe them all. The progressive gear is arranged in such a way that the controlling-lever moves back and forth one notch at a time from the neutral to full speed or reverse in a straight line (Fig. 2), and, while this type of gear is still used on a few

cars, it has now given place to the selective type on nearly all good cars.

Unlike the progressive gears, the selective form (Fig. 3) is operated by a lever (L) which works both out and in and back and forth in an H-shaped guide. This type of selective

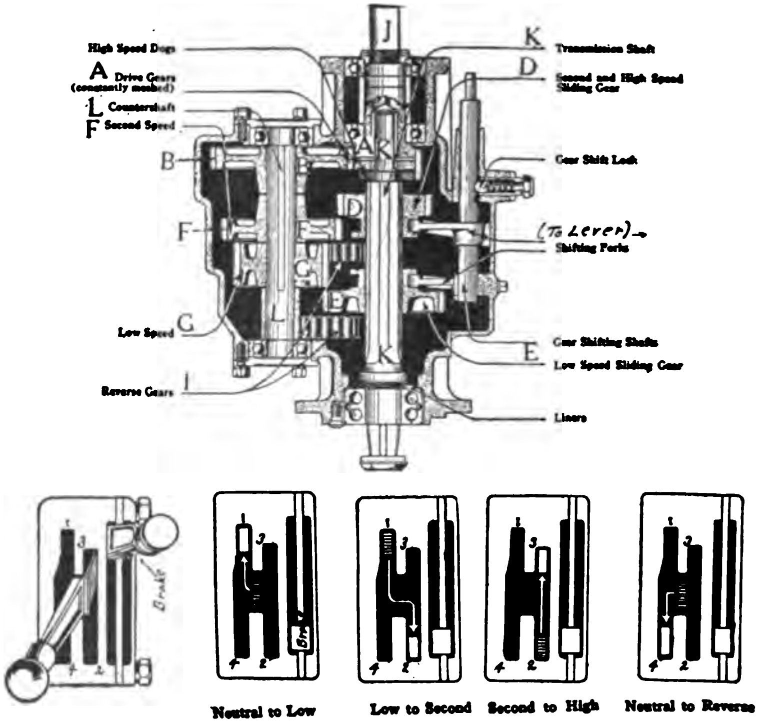


Fig. 3

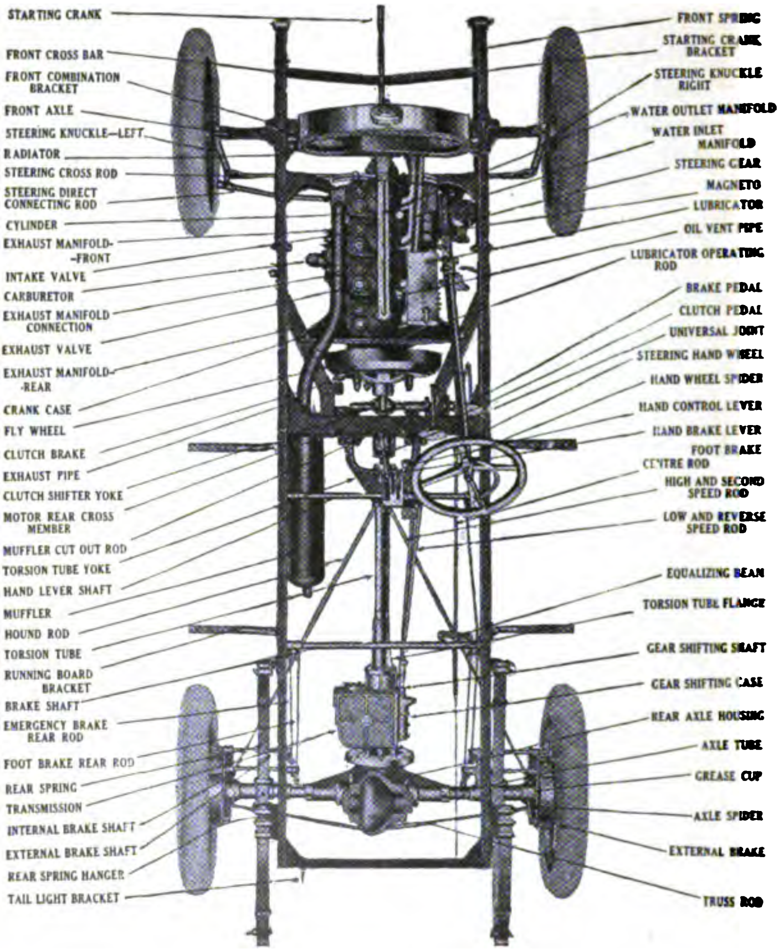
gear provides for three forward speeds and one reverse speed, and operates as follows: the main gear A is immovably fastened to the drive-shaft from the motor J, which fits over the propeller-shaft K, connected to the rear axle of the car. The propeller-shaft is squared, or provided with raised ridges which prevent the gears D and E from turning, but

on which they may readily slide back and forth. The countershaft L carries three gears (B, F, G) immovably attached to it, with the gear B always in mesh with A and the gear G meshing with a small idler (I). The shifting-lever is connected by dogs and rods to forks which bear on the collars of the two gears D, E, and by moving the lever into one or another of the notches 1, 2, 3, 4 either the gear D or the gear E may be pushed backward or forward on the square shaft K.

When the lever is placed in the *inner forward* notch 1 the gear E meshes with the gear G and first or low speed is obtained. By pushing the lever *out* and *back* into notch 3 the gear D is thrown into mesh with F and intermediate or second speed is transmitted, while by pushing the lever into notch 4 the gear D is locked onto gear A by internal teeth and the motor drives the car direct or on high speed. Reverse motion is obtained by moving the lever *in* and *back* into notch 2, thus meshing gear E with the idler I. Leaving the lever in the central space O holds all gears out of mesh, and no motion is transmitted to the propeller-shaft.

Four-speed gears are very similar to this, the main difference being that additional gears are required to transmit the fourth speed.

The precise arrangement of the notches or spaces in the lever-guide in which the lever is placed to obtain any desired result varies with different cars. Low speed may be in and back, out and back, out and forward, or in and forward, but in any event the low speed and reverse are along one plane and the intermediate and high along the opposite plane where three speeds are provided. This is the case with the gear-shift shown, and if the shift is arranged as shown in Fig. 4, A, B, C, the same rule holds good.



PARTS OF AUTOMOBILE CHASSIS

Of course, if the motor was driving the car through one set of gears and you tried to shift to another set while under a load the gears would not mesh, or else they would grate and grind and strip or the entire transmission might

be broken. To make it possible to shift the gears easily and safely while moving, means are provided for disconnecting the motor from the gears. The device used to accomplish this is known as a *clutch*.

Clutches are of three principal types, known as *leather-faced*, *cork-insert*, and *metal-disk*. There are also flat clutches, cone-clutches, metal cone-clutches, and various other forms, but the cone-shaped leather-faced clutch and the metal-disk clutches are the oftenest seen, and their principle is typical of all.

A form of leather-faced cone-clutch is shown in section in Fig. 5. In this type the fly-wheel A is hollow, and its interior circumference is sloped, or at an angle, to the rim. Within this is a cone-shaped wheel or disk, on the face of which is a layer of leather (B). This leather is held up tight against the inside of the wheel by a stiff spring (C) and the friction thus obtained is sufficient to transmit the power of the motor to the driving mechanism of the car. Back of the cone, and connected to it, is a grooved ring (D) over which a dog or collar (E) fits, and this is connected by an arm and rod to a foot-pedal. By pressing forward on the foot-pedal the clutch is drawn back and the wheel revolves freely, while the clutch, relieved of the friction, remains stationary. When this takes place the gear-shifting is done; and, as the revolving wheels and axles carry the driving-gears around and the forward or motor end of the gear-shaft is free, the gears may be readily shifted without danger of injury. The friction-disk clutches consist of a number of circular disks of steel and bronze or other metal keyed to the drive-shaft and clutch-casing alternately. These disks are held firmly together by a strong spring and are released by forcing back the spring by a pedal, as in the cone-clutch. Cork-insert clutches act in the same way, but instead of a

leather surface or disks of metal the insert-clutches depend for a frictional surface upon a number of pieces of cork which press against a metal surface.

The friction-drive used on the well-known Metz and many other cars is very different from any of the above. In the friction-drive there is no true clutch or transmission, the functions of both being combined in the drive itself.

This system (Fig. 6) consists of a metal disk or wheel (A) attached to the drive-shaft of the motor, and a friction-wheel (B) which carries the shaft connected to the wheels. The friction-wheel is faced with fiber or some similar substance, and is pressed against the metal disk by means of a lever and springs, and is so attached to its shaft that it can be moved to one side or the other across the face of the metal disk. When the friction-wheel is in contact with the right-hand side of the metal disk, as shown in Fig. 7, the latter transmits its motion to the friction-wheel in the direction of rotation, as shown by the arrows. As the friction-wheel is moved across the surface of the disk toward the left the motion is transmitted in the same direction, but the speed decreases as it nears the center. When the friction reaches the exact center of the disk (Fig. 8) no motion or power is transmitted; but as soon as it moves beyond the center toward the left, motion is again transmitted, but *in the opposite direction* (Fig. 9).

By this arrangement any speed between the extreme speed of the edge of the disk and the neutral position in the center may be obtained in either the forward or reverse directions. The friction-drive works very smoothly and quietly; its operation is exceedingly simple; there are no complicated levers and gear-shifts; it is easily repaired, adjusted, or inspected; and it is far cleaner than any other type of drive.

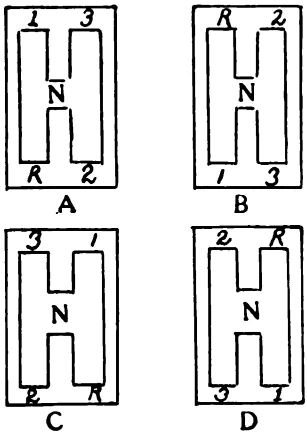


Fig. 4

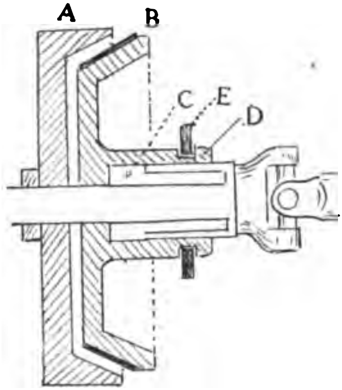


Fig. 5

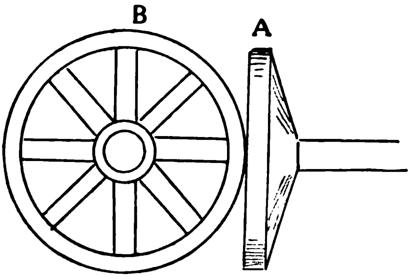


Fig. 6

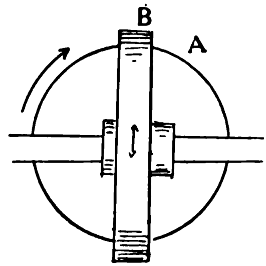


Fig. 8

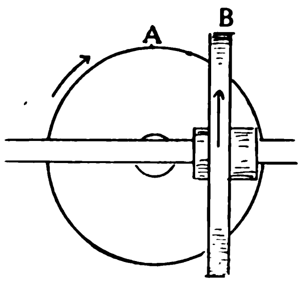


Fig. 7

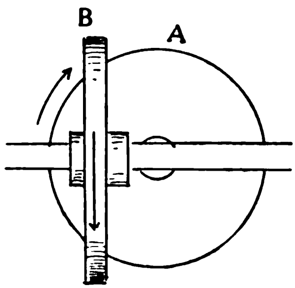


Fig. 9

GEARSHIFTS, CLUTCHES AND FRICTION DRIVE

When properly constructed it will carry any load, but, unfortunately, there is a great deal of wear on the frictional surfaces, and the friction-wheel must be frequently renewed.

The adjustment, care, and successful operation of any clutch depends largely upon the type and make of clutch used. Leather-faced clutches require very little attention; the spring is almost always provided with tension adjustments, and if the clutch slips and increased tension does not remedy the matter the clutch may be cleaned with gasoline and dressed with neat's-foot oil and fuller's earth. If badly worn or burned out, a new leather face can be placed on the clutch at very small expense.

The friction-disk clutches are also provided with a spring adjustment, but they are at times troublesome and may either slip badly or, on the other hand, may *grip* and cause irregular, jerky action of the car.

Some friction-disk clutches are designed to run dry, while others are designed to run in oil. If a dry clutch jerks and grips a little light oil will often improve it, and if a lubricated clutch acts in the same way the clutch should be thoroughly washed out with kerosene and gasoline and filled with fresh, clean lubricant. Slipping is usually due to old, gummy, or hard oil or grease on the disks, and this may be removed by a thorough cleansing with kerosene and gasoline. Frequent adjustments of the springs is seldom necessary and is not advisable; it is better to keep the clutch clean, properly lubricated or dressed, and give it reasonable care in use.

If you allow the clutch to spring into position suddenly when starting the enormous strain thus brought upon it may soon ruin it, whereas it will work smoothly and well for a long time if the clutch is allowed to take hold gradually while starting the car and picking up speed.

Differentials

The differential is a device for distributing the power to both of the driving-wheels equally. When an automobile is turned around one of the rear wheels must travel much faster than the other, as the outer wheel is obliged to travel farther than the inner one (Fig. 10). If both of the wheels were fixed immovably to the same axle one of the wheels would be obliged to slip or drag, thus causing a great deal of resistance and friction and making turning very difficult. If the axle with the wheels attached was driven by power and the vehicle was turned this would be even more apparent, and the vehicle might slew about or upset, aside from the strain and friction produced. To overcome this trouble the wheels are attached to separate axles, and a differential is placed between them.

Some cars have the wheels free on the axles and are driven by chains and sprockets, one on each wheel; others have a single-chain drive to the revolving-axle, while the majority of pleasure cars are driven by a shaft connected to the axle by gears of some sort.

Where two chains and free wheels are used the differential is placed on the short countershaft, or jackshaft, on which the driving-sprockets are placed, but in the other forms the differential is located near the center of the rear axle.

There are various forms of differentials; some constructed with spur-gears, others with bevel-gears, and others with skew-gears, but the general principle of all is similar. In Fig. 11 A, a spur-gear differential is shown. By reference to the cut it may be clearly seen that, while motion or power transmitted to the main gear (1) will transmit its power through the pinions (2) to the internal gear (3) to which the axles are keyed, yet either axle can revolve independently of

the other or can be held stationary while the other revolves. Thus if the right-hand axle is held immovably the power is transmitted to the left-hand axle, and the small pinions of the right hand merely turn around on the internal gear. (Fig. 11 B.) By this arrangement the two wheels drive

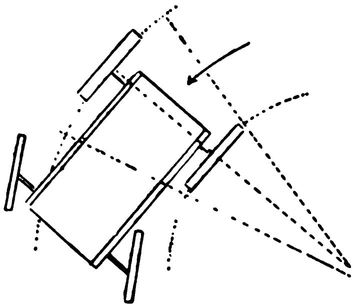


Fig. 10

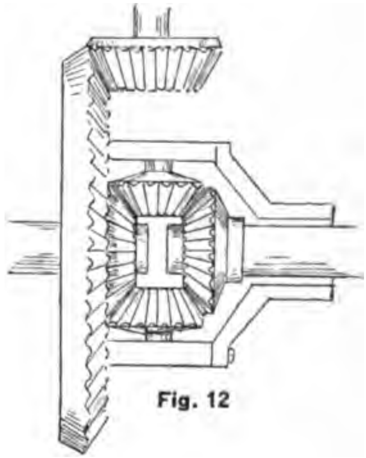


Fig. 12

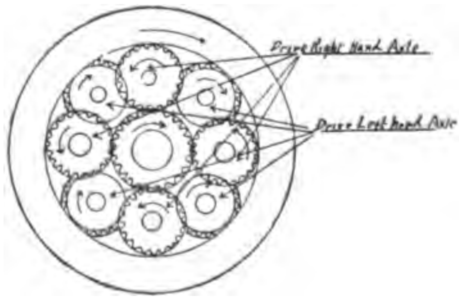


Fig. 11 B

Fig. 11 A

equally when the car is traveling in a straight line, but as soon as a turn is made the power is distributed in proportion to the resistance of the wheels and the distance they travel.

The same principle is involved in the bevel-gear differen-

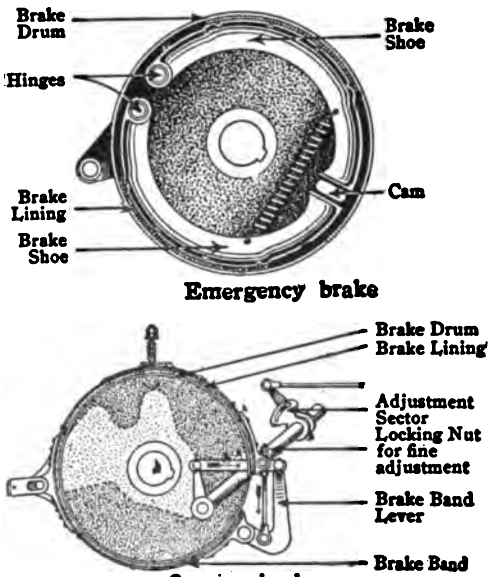
tial shown in Fig. 12, the only difference being that bevel-gears are used instead of spur-gears. Differentials will withstand a great amount of abuse and lack of care, but they are a most important part of the car and should be frequently inspected, well lubricated, and occasionally adjusted when necessary.

A differential is usually inclosed in a tight case, or housing, and this should at all times be kept tight and well filled with soft grease. If the differential jerks or grabs and the car runs unevenly the trouble should be located and remedied at once. The fault may be in the adjustment of the driving-pinion or gear or in one of the bearings or even in the large master-gear. Sometimes a broken tooth or bearing or a bit of metal will get into the gears and play havoc with them, but as a usual thing the troubles are merely lack of adjustments to take up ordinary wear. The master-pinion is riveted or bolted to a disk or spider, and these bolts or rivets frequently become lost or worn. By opening the differential housing and examining the master-gear you can readily determine if this is the trouble. The small driving-pinion is held in position against the master-gear by roller or ball bearings inclosed in a housing, which is usually provided with an adjustable collar. If this collar becomes loose, or the bearings or gear become worn, the pinion may *ride* up on the master-gear and cause a great deal of trouble. If this occurs it may be located by an examination of the interior of the differential or by the rear-axle housing working up and down on the propeller-shaft housing. The remedy is to adjust the collar until the small pinion meshes properly with the main gear. Care should be taken not to get it too tight, as in that case undue friction and wear will result and the gears will hum or roar when the car is in motion.

Brakes

All motor-vehicles are provided with brakes of some sort, and the majority have two separate sets known as *service brakes*, or foot-brakes, and *emergency brakes*, or hand-brakes. The exact arrangement of the brakes and their design and construction varies in different cars, but in a general way all modern brake systems are similar.

A very common method is to arrange the foot-brake on the outer circumference of the brake-drum on the rear wheels and the emergency brake on the inside (Fig. 13). This is known as an *external-contracting* and *internal-expanding* brake from the fact that the foot-brake acts by contracting on the drum while the emergency brake acts by expanding against the inside of the drum. Other makers use the foot-brake inside and the emergency outside, while some designers employ a foot-brake on the drive-shaft or on a jackshaft, with the emergency brake only on the wheels. Brake-bands may be of spring metal lined with a frictional substance composed of asbestos and wire netting, or they may be of metal



Service brake
Fig. 13

alone; many cars have the foot-brake lined and the emergency brake plain metal, or *vice versa*. The mechanism and action of any form of brake is so simple and so easily understood that detailed explanations or directions for their adjustment and care are unnecessary. The brakes are a vital portion of the automobile and are all too often neglected. Keep the various joints, pivots, and all working surfaces clean and well oiled. Try the brakes frequently by jacking up a wheel and endeavoring to turn it while each brake is thrown on in turn, and keep the adjustments tight enough so that the brakes will grip and stop the car within its own length under ordinary conditions. If the surface of a lined brake is badly worn or glazed, remove the old lining and reline it with new material, but until badly worn occasional cleansing with gasoline and a little scraping to remove the glazed surface will do much to improve the action of the brakes. Brake-rods are usually connected to the lever or pedal-rod by means of a pivoted piece of metal known as an *equalizer*. If this device becomes stuck or does not move readily one brake will grip more than the other, and you should examine the equalizer frequently. Oil the bearings or pivots and see that all the parts of the brake system are in good working order; many a life has been sacrificed and numberless good cars smashed up through faulty, worn, or badly adjusted brakes.

Bearings and Axles

The bearings which support the axles and wheels of an automobile carry all the weight and load, and are subjected to tremendous shocks and strains.

So well made are modern bearings that they run smoothly and uncomplainingly for month after month and for thou-

sands of miles with very little care, and this fact leads many auto-owners to neglect the bearings, upon which so much depends.

Most bearings used in automobile construction are of two kinds, known as *ball-bearings* and *roller-bearings*. Ball-bearings are of various types, and, while formerly used throughout the axle construction, they are now used mainly for the lighter parts in conjunction with roller-bearings or for the front wheels. The principal forms of ball-bearings are the *annular* and *cup-and-cone* shown in Fig. 14, A, B.

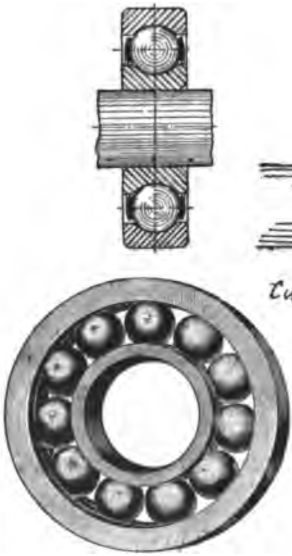


Fig. 14 A

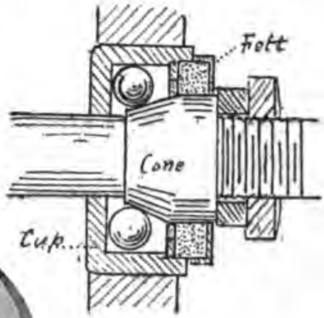


Fig. 14 B

Ball-bearings should be kept just tight enough to prevent play and loose enough so that they turn very easily. If cared for properly and kept well adjusted and thoroughly lubricated, ball-bearings will show practically no wear or trouble for a very long time. If allowed to run dry, loose,

or too tight, however, they will cut and wear out very soon. A broken or scarred ball will soon cut the cup or the cone, and the other balls, striking the injured spot, will rapidly wear out. Examine and clean the bearings from time to time and test them frequently for looseness or play. If a ball shows ever so slight a crack or rough spot, *all* the balls should be replaced by new ones. If a single new ball is placed among the old ones you will have trouble; although the balls may appear perfect, yet they are invariably somewhat worn, and the new ball, being slightly larger, will take most of the load and will either be damaged or will cut the cone or cup. If the cones or cups are worn, cracked, or damaged, put new ones in their place, for leaving a worn one will merely mean more trouble and far greater expense in a short time.

Use a good grease in lubricating the bearings, and be sure that no dust, dirt, or grit gets into them.

A felt washer is employed to keep out the grit and dust, and in removing and replacing this use great care not to let it fall on a gritty or dusty surface. If the washer is worn, hard, or out of shape use a new washer; a felt washer is only a matter of a few cents, but its condition may mean a great many dollars lost or saved.

Roller-bearings are of various forms and types, but the hollow or *Hyatt* bearings and the *Timpkin* types (Fig. 15, C, D) are the most often used. Roller-bearings require rather less attention than ball-bearings, but a proper adjustment, thorough lubrication, and freedom from grit and dust are essential to their proper operation and long service.

The rear axles of an automobile require very little attention, for they are safely protected and out of sight within a steel cover or housing, and the only wearing surfaces are at the bearings at the two ends.

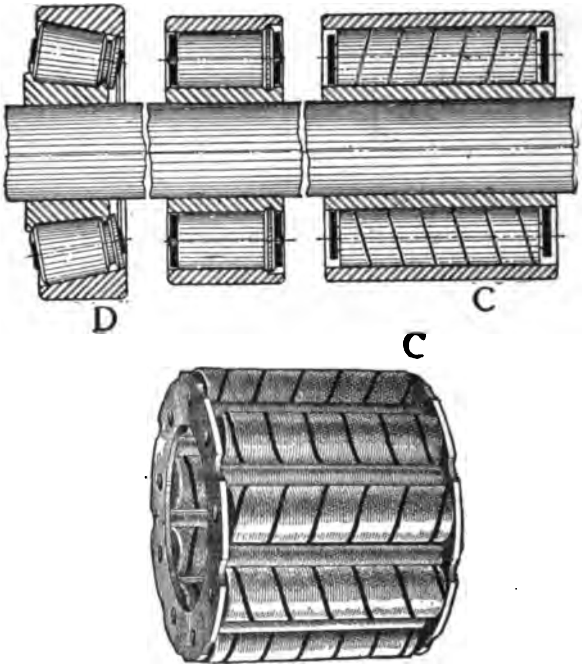


Fig. 15

Axles *will* occasionally break, however, and if anything goes wrong in the differential you may have to remove them, so it is a good plan to learn something of their construction and design in order to understand just how to remove or replace them.

There are two general types of rear axles used in modern cars, known as *full-floating axles* and *semi-floating axles* (Fig. 16, A, B). In the full-floating type the axles have one end fitted into the gear of the differential, with the other fastened into the wheel; but the bearings do not touch the axles, but are supported by the housing and wheel at one end of the axle and by the differential and housing at the other. By this method no weight whatever is supported by the axle

itself and its only function is to transmit the driving-power. The semi-floating type, on the other hand, is fastened to the differential gear and to the wheel, but the bearings are between the axle and the housing, so that the entire weight of the rear part of the car, the differential, and the axle-housing must all be supported by the axle proper and its bearings. In taking out a full-floating axle the wheel may be disconnected readily, and the entire axle withdrawn without the use of tools or without taking apart the differential or the housing. Semi-floating axles require very different treatment. In these axles it is usually necessary to take down the entire rear-axle housing and separate the differ-

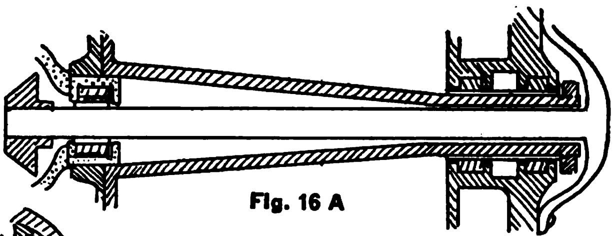


Fig. 16 A

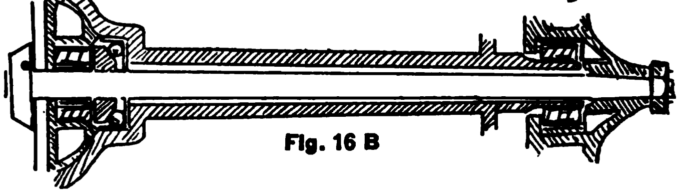


Fig. 16 B

ential in order to withdraw an axle, and this is a very hard, dirty, and disagreeable job. Luckily, it is very seldom necessary unless the axle breaks or some other unusual or unexpected accident occurs. Some semi-floating axles are, however, as easily withdrawn as those of the full-floating type.

It is important, however, to keep the wheels snugly attached to the axles, for a very little play will soon wear the

keys and key-slots, and the wheel may either turn completely around on the axle or it may work loose and fly off completely. Most wheels on the semi-floating type are secured by keys set in keyways in the axles and the hub and by a nut threaded on the outer ends of the axles. This nut should *always* be a castellated nut, with a heavy cotter-pin to prevent it from working off; a great many serious accidents have occurred through neglecting this simple matter.

Steering-Gear

The safety of your car and its occupants depends more upon the steering-gear than any other one part of the machine. A deranged, loose, weak, or otherwise faulty steering-mechanism may result in a very bad accident without the slightest warning. Therefore give the most minute care and attention to this part of your car.

There are really but four parts to a steering-gear, and they are all where they may be readily inspected, oiled, adjusted, and cared for. The parts of the gear are, first, the *steering-column*, which bears the steering-wheel at one end and a small gear at the other; second, the *steering-arm*, with its shaft and gear which engages the gear on the column; third, the *drag-link*, which connects the steering-arm with one wheel; and, fourth, the *distance-rod*, which connects the two wheels and keeps them the right distance apart.

There are various forms and arrangements of steering-gears, but those mainly in use on pleasure cars are of the *worm-and-gear* type (Fig. 17), but *rack-and-pinion* systems (Fig. 17 B) are used on a great many commercial cars and on many of the older pleasure cars.

All steering-gears have adjusting devices provided for

taking up the wear, and you should constantly attend to this matter and always keep the steering-gear just tight enough to give perfect control and at the same time not so tight as to make it difficult to turn the wheel. Never try to

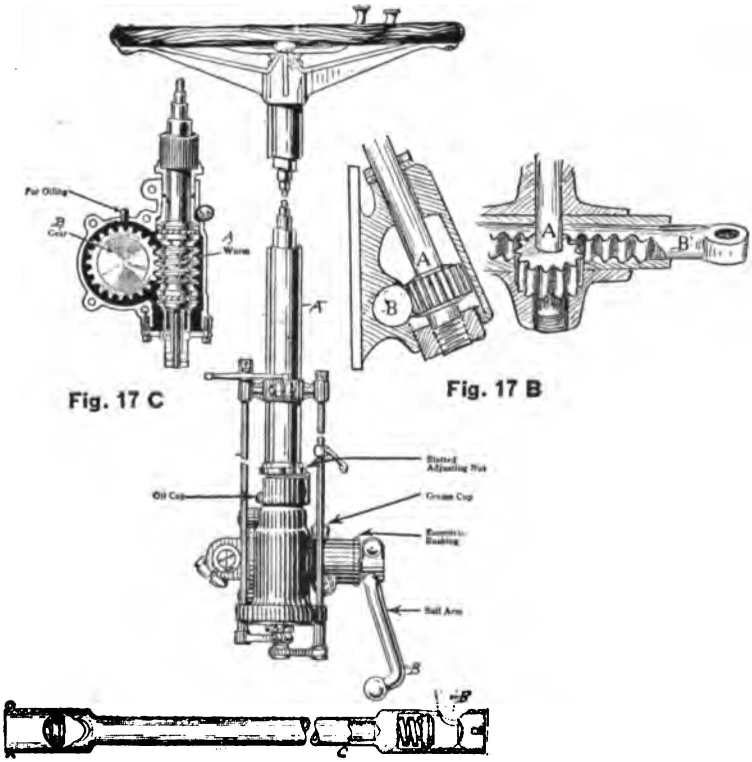


Fig. 17 C

Fig. 17 B

Fig. 17 A

adjust a steering-gear while the car is stationary and resting on the wheels; either jack up the car or else make the adjustments gradually and test them by operating the steering-gear while the car is moving.

The steering-arm usually passes through a bearing or

bushing on the frame of the car, and, as this receives a great deal of wear and strain, it becomes loose comparatively soon. Most arm-bushings are adjustable and may be readily tightened up, but if no adjustment is provided a new bushing or bearing should be furnished whenever the old one becomes worn and loose.

The extremity of the arm is connected to the drag-link by means of a ball-and-socket or similar joint (Fig. 17 C), and this joint should be kept well greased, adjusted so that there is no undue play, and, if possible, covered with a leather boot. The same rules apply to the other end of the drag-link where it is connected to the steering-knuckle of the wheel and to both terminals of the distance-rod. The steering-knuckles and spindle of the front wheels are mounted on bearings between two forks and on the ends of the front axle (Fig. 18), and the oil or grease receptacles on these joints and bearings should *always* be kept well filled. By jacking up the front axle you can determine if there is any undue play in the spindle-bearings by shaking the wheels back and forth. If it is impossible to take up this looseness by the means provided you should not hesitate to put in new pins or

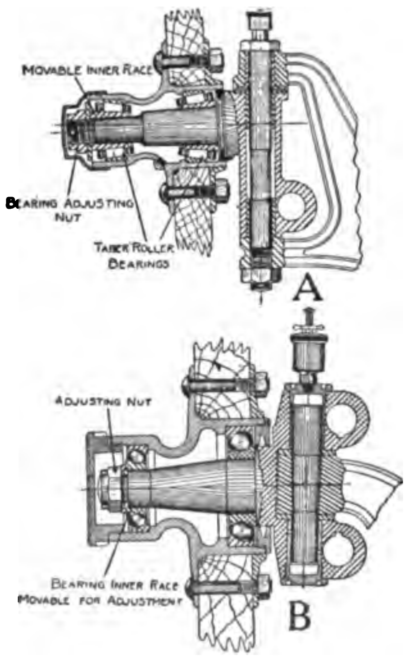


Fig. 18

bearings, for looseness here interferes seriously with the steering and in addition wears the tires out very rapidly. The importance of keeping the front wheels in line is often overlooked even by experienced owners. If the wheels are out of line vertically (Fig. 19, A) you may be sure that there is a badly worn bearing, pin, or spindle on one or both of the wheels or that the front axle is bent. If, on the other hand, the wheels are out of line horizontally (Fig. 19, B) the fault may be remedied by adjusting the distance-rod; by loosening the locking-nuts and screwing out or in on the rod any reasonable adjustment may be made.

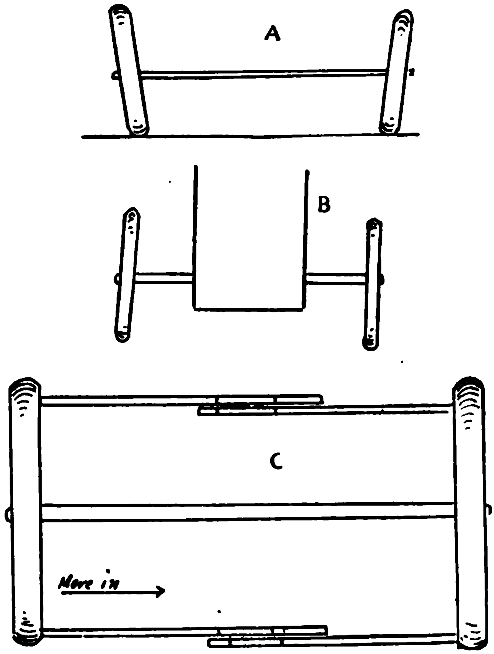


Fig. 19

It is far easier to see if the wheels are out of line vertically than horizontally, but the latter fault is easily ascertained by using a string or, better still, two light sticks or rods, each a little more than half as long as the distance between the wheels.

To align the wheels turn one wheel until it is parallel with the frame and in line with the rear wheel. Then place one rod against the inner *rim* of the wheel directly in front of

the hub, and place the other rod against it, with its end just touching the inner rim of the other wheel. Mark a couple of lines across both rods (Fig. 19, C), and proceed in the same way to measure the exact distance between the wheels from rim to rim directly back of the hubs. If you discover that the front rims are farther apart than the rear you must screw out on the distance-rod until the rods show the same distance at both front and rear. If, on the other hand, the front rims are nearer together than the back you must screw *in* on the distance-rod and bring the rear edges closer together until both measurements are the same.

You should take plenty of time and care in doing this, for if the wheels are in the least out of line the tires will wear very rapidly and the strain on the steering-mechanism will be much greater than normal.

The above are really all the parts of the car that are of a mechanical nature or require any explanation or description or that have any direct relation to the motor, but you should always bear in mind that "lost motion means loss of power," to say nothing of noise, rattle, and wear, and you should invariably try to keep your car in as perfect condition as possible.

If you are fortunate enough to have a fine new car with all the latest fads and improvements you should show your appreciation of such a splendid piece of work by keeping it clean, well oiled, polished, and neat, and "up to the mark" at all times.

If, on the other hand, you are obliged to content yourself with an old but faithful car with out-of-date body, antiquated motor, and humble equipment, you may accomplish a great deal by giving it proper care and attention. An old-fashioned car with clean paint, carefully adjusted and lubricated parts, and brightly polished brass is far more

credit to its owner than the latest model covered with dirt and mud, with tarnished metal, dry bearings, and loose, rattling steering-rods and brakes. An old motor well cared for will outlast a new motor which is neglected and abused.

Too many boys, and men also, are apt to judge a car by its model or age. If people would only learn to judge machines by their reliability, performance, and efficiency it would be of vast benefit to both the public and the automobile industry, and many a luxuriously upholstered and finely painted car would be consigned to the junk pile in favor of less pretentious but mechanically superior machines.

Chapter XIII

MOTOR-CYCLES AND CYCLE-CARS

FOR speed, handiness, and low upkeep the motor-cycle leads all other forms of motor-vehicles. In a way a motor-cycle is merely a particularly strong and well-built bicycle provided with a motor. In fact, some of the earlier forms were nothing more than motor-equipped bicycles. To-day, however, motor-cycles are designed with special reference to the strains, stresses, and vibrations caused by tearing at sixty miles an hour across country impelled by a powerful motor. Motor-cycle engines are of the air-cooled, four-cycle type, and may be of one, two, or more cylinders. In their principle, operation, and care these motors do not differ greatly from others of similar forms, but, as they are much smaller and more compact, they should be given even greater care and attention than larger motors.

Motor-cycle engines have numerous details of construction which are designed to accommodate the motor to the limited space on the machines, and some of these constructive peculiarities are very important. The Iver-Johnson, for example, employs a crank and fly-wheel of very strong and compact construction (Fig. 1) in which the connecting-rod is inclosed within the two halves of the fly-wheel which is riveted to the crank. The crank itself consists of two separate parts connected by a taper projection on one half wedged into a recess on the other side, and thus forming the crank-pin.

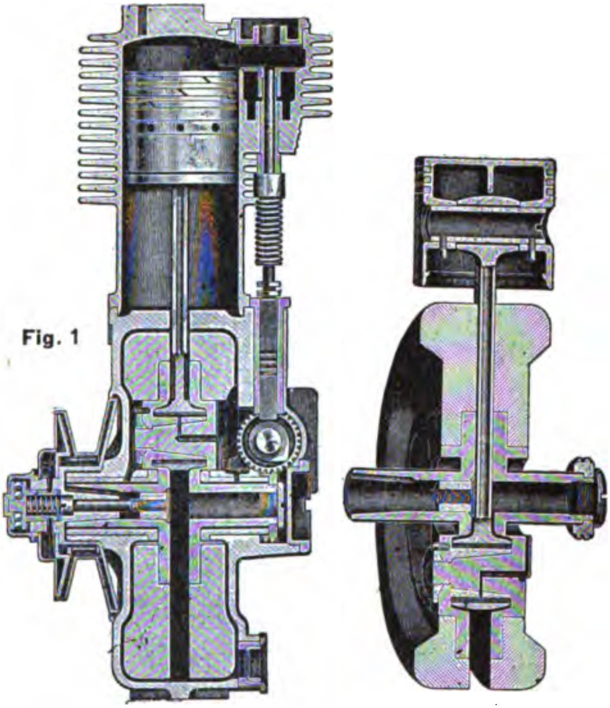


Fig. 1

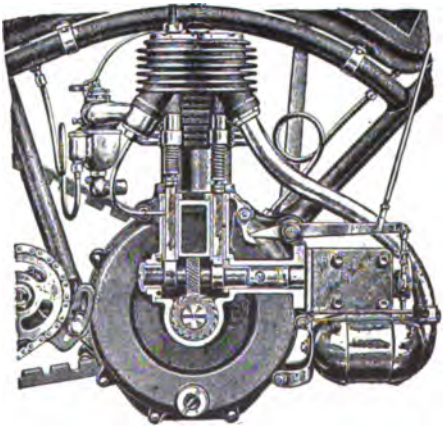


Fig. 2

CRANKS AND VALVE ACTION OF MOTOR-CYCLE

The valves in this machine are all operated and the magneto driven by a single cam-shaft, which is operated by a simple spiral gear (Fig. 2), thus greatly reducing the number of working or moving parts. The control of most motor-cycles is through various rods, wires, and levers to the handles on the handle-bars. By turning one handle to right or left the throttle is opened, while the other grip controls the spark. Provision is also made for slightly lifting the exhaust-valve to decrease compression and permit easy starting. Modern motor-cycles are all provided with a free clutch, so that the motor may be operated without transmitting its motion to the driving-wheels, but gear-shifts or transmission devices are not usually employed.

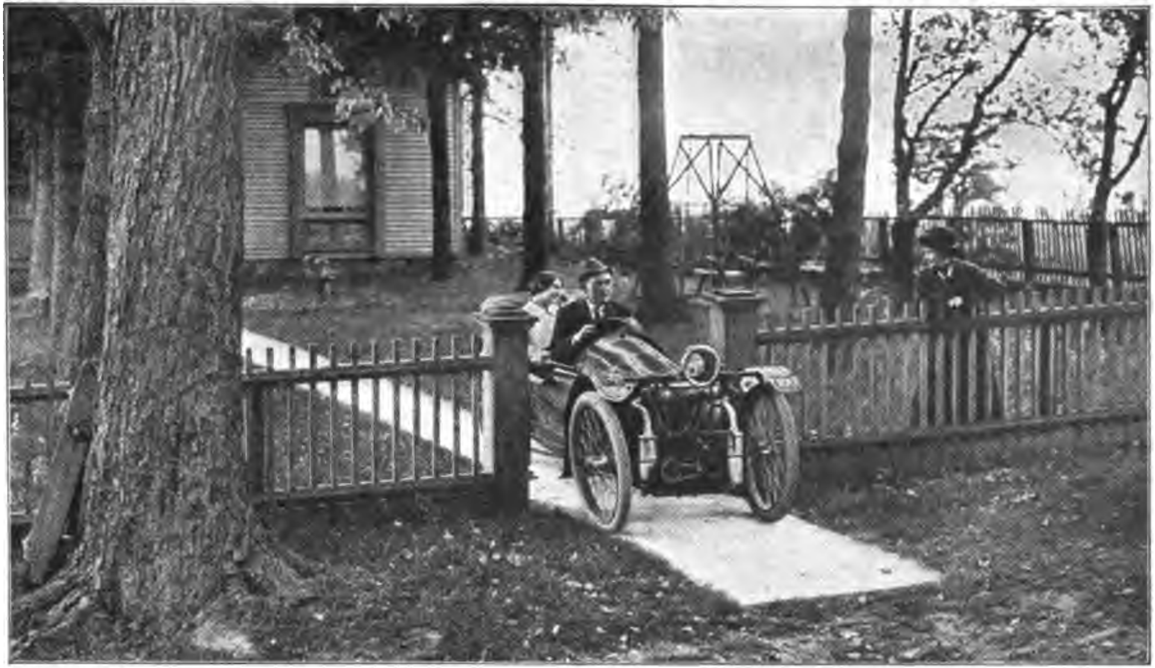
The care and adjustments required for motor-cycles are practically identical with those for automobile motors, and detailed directions are not necessary.

Cycle-Cars

Within the past year or two an entirely new type of motor-vehicle has made its appearance in America and abroad. This is the *cycle-car*, a machine designed to fill the gap between the motor-cycle and the automobile, and in some respects resembling each, but greatly differing from both.

The cycle-car was developed through the demand for a low-priced, fast, and light vehicle with seating capacity for two passengers and with very low upkeep cost. In America the cycle-car has not as yet been developed to any great extent, but in Europe there are scores of different models in use.

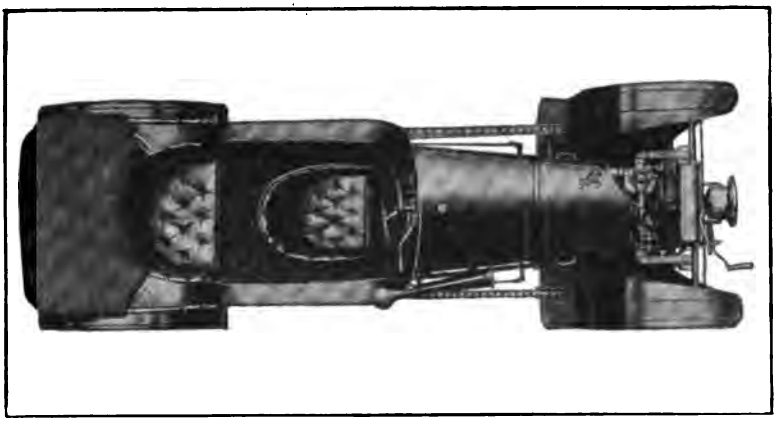
The true cycle-car is a light-weight, narrow-gage automobile of the simplest construction possible and with many motor-cycle features. Cycle-cars may or may not have

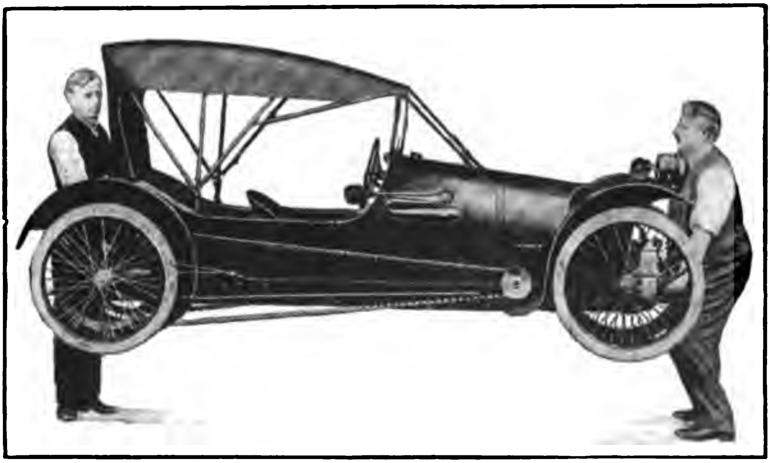


THE CONVENIENCE OF A CYCLE-CAR

standard types of motors, transmissions, differentials, etc., but the more simple designs are more properly true cycle-cars, the exact definition of cycle-car being rather indefinite. The term originated in England and was first applied to motor-cycles with three wheels and a light basket-like body, something like an ordinary side-car. Later cars were built with four wheels and a true body, and the term cycle-car was transferred to these. The original cycle-car of the four-wheeled type was the *Bedelia*, built by M. Barbeau, of Paris, in 1910. This little car was really a miniature automobile driven by a motor-cycle engine and with a belt-drive from pulleys on a countershaft to pulleys on the rear axle. There was no clutch, and in its place arrangements were made by which the rear axle could be drawn forward by a hand-lever, thus tightening or loosening the belt and at the same time drawing the pulleys against brakes.

The steering-wheel was a wire-spoked affair, and turned the front axle by means of a drum and a steel cable. The weight of this pioneer car was under 400 pounds, its length was about 100 inches, and it was 36 inches wide and 36 inches high. Although the car was of novel, revolutionary, and freakish design, yet in a 138-mile road race it surprised even its inventor by averaging 38 miles an hour. Later on it developed a speed of over 55 miles an hour, and was such a huge success that cycle-cars at once became the rage throughout Europe. So rapidly did the makes and designs increase, and so widely did they vary, that it is now almost impossible to draw the line between a true cycle-car and a small automobile. The English definition, "A mechanically propelled vehicle whose chassis does not exceed 800 pounds and whose total cylinder capacity does not exceed 1,100 cubic centimeters," might apply just as well to certain small automobiles; in fact, a great many





THE IMP CYCLE-CAR

so-called cycle-cars are merely small, light, and cheap automobiles. Strictly speaking, a true cycle-car must be equipped with a motor-cycle or cycle-car motor of low power, and motor-cycle practice must be followed in the transmission, control, and other mechanical devices.

Whether this is followed or not, or whether the vehicle may or may not be a true cycle-car, is of little real importance. The great point in favor of the cycle-car, and upon which its future depends is the low price at which it may be sold, thus placing all the pleasures of motoring within the reach of nearly every one.

Types of Cycle-Cars

Among the leading types of cycle-cars made in America there is a great deal of variation in size, capacity, cost, and design. Some of the more noteworthy are as follows:

Carnation. Built by American Voiterette Company, Detroit. This little car weighs 710 pounds, has a 100-inch wheel-base, a 44-inch tread, and a 22-horse-power motor with four cylinders. The transmission allows of three forward and one reverse speeds, with center drive, right-hand control, wire wheels, and 30" x 3" tires.

Economycar. Built by Economycar Company, Indianapolis. Weight, 393 pounds, with 106-inch wheel-base and

THE TWOMBLY CYCLE-CAR

36-inch tread. Motor, two-cylinder motor-cycle-type engine of 8 to 10 horse-power. Drive by silent chain and belts.

California. Built by California Cycle-Car Company, Los Angeles. Weight, 450 pounds; tread, 44 inches; wheel-base, 102 inches. The engine is air-cooled, with two cylinders, and develops 10 horse-power. Valves are mechanically operated, overhead type. Transmission to countershaft by friction-drive and by two V belts to rear wheels. Adjustment of belts is obtained by a lever action similar to that on the original Bedelia car.

Twombly. Built by Twombly Motor Company, New York City. Model B has a wheel-base of 96 inches, tread of 38 inches. Motor V type, piston-valve of 10 horse-power. Countershaft with differential, driven by friction transmission and by side-chain to rear wheels.

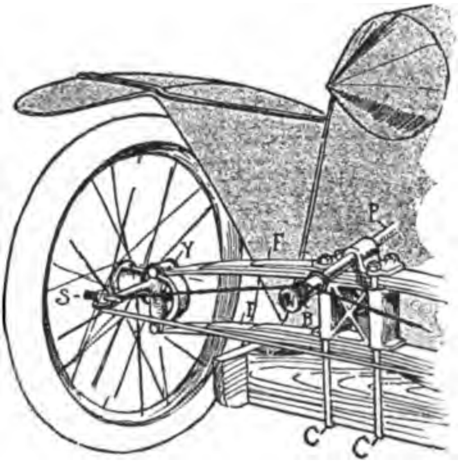


Fig. 3

Imp. Built by McIntyre Company, Auburn, Indiana. This car has many original and unique features, particularly in its spring construction. Instead of having axles there are two flat springs set crosswise of the frame and with their ends attached to yokes between which the wheel-spindles are fitted; those in front being attached to a pivoted steering-knuckle, while those in the rear are fastened to a rigid arm (Fig. 3). The car is equipped with ball-bearings throughout and has but two gears—the timing-gears.

The motor (Fig. 4) is of the V type, air-cooled, with a heavy fly-wheel, and delivers from 10 to 12 horse-power. The transmission is of the friction type, and the rear wheels

Fig. 4

are driven through long *V belts* outside of the car. The steering-post operates a bobbin around which are steel cables leading to the steering-arms of the front wheel-knuckles and kept taut by stiff springs (Fig. 5, which shows the side view).

This little car is so light that two men can readily lift it, it is small enough to pass through an ordinary gate or doorway, and yet it can travel at 50 miles an hour with safety, can climb hills and ford streams with the best cars, and in actual tests has out-traveled powerful six-cylinder machines.

The cost of maintenance on these cars is very low; from 25 to 40 miles may be obtained from one gallon of fuel, and the light weight of the car keeps down excessive tire expense, which is still further reduced by the small size of the wheels. The cars are so simple mechanically, so readily

accessible, and of such small size that repairs, when necessary, are easily made and new parts are inexpensive.

The above descriptions will give some idea of the construction and principle of the leading cycle-cars made in this country, several of which are already widely used. They will apparently become as universal favorites in America as abroad, and every boy interested in motor-vehicles of any sort should keep posted as to the development of this new type of car.

The care, operation, and adjustment of a cycle-car are the same as for an automobile or motor-cycle, but the

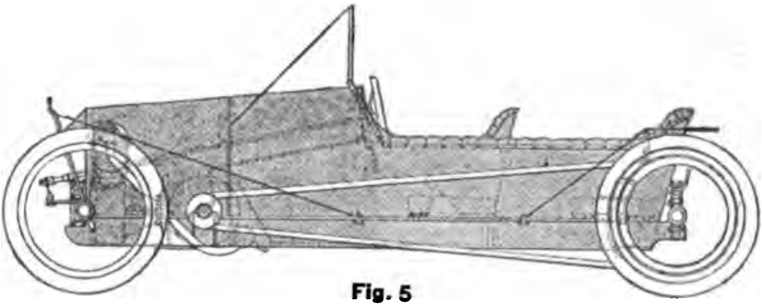


Fig. 5

motors are, as a rule, more like the motor-cycle engine than the automobile, although many of them are water-cooled.

Any smart boy who is handy with tools and can get together some old parts of motor-cycles, automobiles, etc., can design and build some sort of a cycle-car, but the cost of the well-built standard machines is so low—from three hundred to five hundred dollars—that it scarcely pays to build one except for experiment and practice.

In designing or building a home-made cycle-car aim for simplicity, low center of gravity, and easy control.

A great many builders of cycle-cars have neglected these points, and in their ambition to furnish the most value for the money they have produced small automobiles instead of true cycle-cars.

Part V

TROUBLES AND REPAIRS

Chapter XIV

PREVENTING TROUBLES

THE old adage that "an ounce of prevention is worth a pound of cure" is particularly true of gasoline motors. More than two-thirds of the troubles, breakdowns, and accidents to motors, motor-boats, and motor-vehicles are due to neglect or carelessness. The common idea that a motor is a perverse and stubborn thing and liable to fail at a most inopportune time without any reason is pure nonsense. The modern motor is a thoroughly well-made and reliable machine, and it will never stop, give out, or refuse to operate without some good and sufficient reason. If a motor runs five minutes steadily there is no reason why it should not run for hours, days, or weeks unless some detail is overlooked or omitted.

Every motor must have fuel, electricity, and oil in order to run, and yet time and again a motor-boat or automobile will stop suddenly, and the operator will search high and low for the trouble only to discover finally that he has neglected to furnish gasoline or oil, or that his batteries are exhausted.

The majority of motors are operated by people with no mechanical knowledge or skill, and it is surprising how little trouble the motors give when we consider the treatment they receive.

If you wish to avoid troubles and delays with a motor you must give it a reasonable amount of care and attention.

A motor carefully looked after and frequently cleaned, adjusted, and *tuned up* will seldom require taking down or overhauling. It never improves a motor to take it down too often, but an overhaul is necessary when a motor is neglected or not kept right up to the mark all the time. Lubrication is a very important item to look after. There may be plenty of oil in your tank or motor-base, and yet the bearings may not be getting any lubrication. Bits of dirt, metal, waste, or other substances may clog a pipe or an oil-hole and prevent the oil from flowing. The old oil should be drawn off from time to time, the oiler (if of the gravity or force-feed type) cleaned with kerosene, and new oil furnished. If the motor has an oil-pump it is well to disconnect a pipe now and then and see if the oil is squirting with considerable force when the motor runs. An unlubricated or dry bearing will heat, seize, and cut, and will play havoc in a very short time. Poor, broken, wet, oil-soaked, or loose wires are a great source of trouble. Keep the wires out of dirt and grease, away from hot pipes or any object against which they may rub, and renew them whenever the insulation becomes soft or broken. Before starting on a run and after the return from every trip look the motor over thoroughly; tighten every nut or bolt that is the least bit loose; see that all the cylinders fire every time; drain the bottom of the carbureter to remove any dirt or water; see that all grease-cups and oil-receptacles are filled; be sure that there is water in the radiator, and test each wire for looseness.

If you attend to these details before leaving home you will save a lot of trouble on the road or on the water.

If a motor knocks, pounds, rattles, or makes any unusual noise stop it immediately, unless such a stop would endanger life, and find out where the trouble is before you proceed.

Never leave home in a motor-boat, automobile, or other vehicle without a proper assortment of tools, spare parts, and supplies. They may at times be a nuisance, and you may carry them for months and years without needing them, but when the occasion *does* arise you will thank your stars that you carried the tools and parts along, and their value in time of necessity will more than make up for all the trouble they have been.

Overhauling

Overhauling a motor means taking it to pieces and going over all its various parts, replacing those portions worn or broken, tightening up joints and bearings, cleaning every part thoroughly, and putting it together again.

Anybody can take a motor down and put it together, but a good deal of knowledge and skill is required to do it properly, and if done carelessly or improperly the motor may be ruined.

I would not advise any amateur or young boy to attempt an overhaul of a large or complicated motor, but a small motor may be readily overhauled.

The most important items to attend to in an overhaul are the bearings, the timing or other gears, the cams and valve mechanism, the valves, the piston-rings, and the oiling system.

Most bearings are so constructed that they can be readily tightened up without overhauling the motor by simply removing the lower half of the crank-case. Some bearings are provided with thin shims of metal, and by removing these one at a time and frequently testing the bearing, any desired tightness may be obtained. Other bearings are made without shims, and the two sides must be filed down

slightly to tighten them up. Still other bearings are adjusted by special devices of nuts and screws. If a bearing is cracked, cut, broken, or badly worn it must be replaced with a new one. When this is done the new bearing must be *scraped in*, a delicate and difficult job which requires the hand of a thoroughly competent mechanic.

On small motors the connecting-rod and main bearings of the shaft should be tight enough so that there is absolutely no up-and-down or side play, but they should be free enough to turn readily. Large motors and automobile engines should have the bearings tightened up until you can barely turn the motor over by hand. If an automobile motor is tightened up properly it is usually necessary to tow it with another machine, throwing the gears in mesh, in order to start the motor. After running a short time it will turn easily enough. Most amateurs make a grave mistake in not getting the bearings tight enough. *Never* tighten up a bearing when dry; always spread a good layer of oil over the shaft or pin and in the bearing before adjusting it; if you do not attend to this detail there will be no room left for an oil film, and the bearing will cut and be ruined in a few moments.

When tightening bearings proceed as follows: Tighten one bearing at a time. When the first is right, loosen the nuts slightly and tighten the next one; loosen this after proper adjustment is obtained and proceed with the next, and so on until all are finished, when the bearing-nuts may be all tightened up. By this method you can readily test each bearing separately, whereas if you adjust and tighten one bearing after the other and leave the nuts on tight while adjusting the others you cannot possibly tell which one is too loose or too tight. After all the bearings are adjusted and the nuts tightened you may still find that there

OVERHAULING A MOTOR

is play or that there is undue friction somewhere. This often occurs, for the shaft may be slightly bent or out of line, or a bearing may be uneven or rough in some one spot. To locate the trouble you must loosen the nuts to each bearing in turn, a little at a time, trying the shaft or rods as each is loosened up. As soon as the tightness ceases you can be sure it was in the last bearing loosened. If there is any looseness noticeable you must locate it by tightening up on the bearing where the play occurs. Do not file away a bearing-cap or remove shims unless you do it very gradually. A very small amount—even 1/250″—will often make a great difference in the fit of a bearing.

In taking down a motor be sure and mark every piece so that you cannot fail to put it back in its proper place. Each cylinder, valve-cap, valve-gear, connecting-rod, piston, etc., should be marked. Mark each cylinder 1, 2, 3, 4, etc., and mark the parts of each cylinder to correspond. This is easily done with a prick-punch, and will save a great deal of trouble. Make one prick for 1, two for 2, etc., and of course make the marks on some part of the object that is exposed or does not rub or slide on another part. In taking down the gears be *very sure* to mark each gear where it meshes with another, and have the motor in a certain definite position before taking the gears off for marking them. If you turn the motor over until the first piston is at the top of its stroke and then mark each gear you will have no trouble in replacing them correctly. Mark the gears where the teeth mesh, making one, two, three, and more marks with the prick-punch to distinguish the various points, and if you have any doubts about your memory make a diagram on paper showing the relative position of the gears and their markings. Fig. 1 shows the front end of a motor with the various gears marked ready to take them down.

The magneto, if the motor has one, or the timer, will be set at a certain point on the shaft that drives it. Merely marking the gears will not help you in replacing these, and it is necessary for you to mark the magneto or timer connection and the shaft to correspond, as shown in Fig. 2.

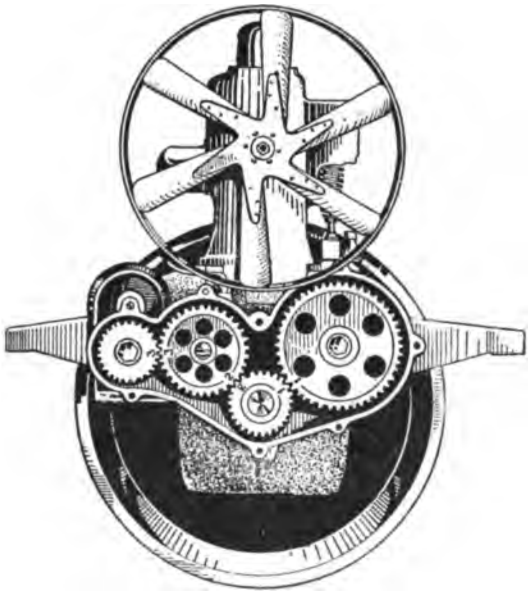


Fig. 1

Mark each wire and the place it is fastened to before removing it. Wires may be marked by tying numbered tags on them or one, two, three, or more bits of twine may be tied around them. The connections where they belong may be marked by a prick-punch to correspond with the strings or tags, or if the part is too small or too delicate to mark with a punch it may be tagged to correspond with its proper wire (Fig. 3). Many motors have bolts, screws, and nuts of special kinds, while others employ two or

three different kinds of threads on the bolts, screws, etc. Sometimes it is difficult to distinguish between two distinct threads by sight, and unless the motor you are working on has all of the screw-threads standard it is best to place the nut back on each bolt as soon as it is removed. A great deal of time and confusion may also be saved by placing all the bolts, screws, etc., for certain parts together in a box or envelope and labeling them. Thus, all the bolts that secure the cylinders to the crank-case may be placed in one box, all the screws that secure gear-case covers in another, all the bearing bolts and nuts in another, etc.

Never put back any bolt, screw, nut, or other part without cleaning it in gasoline or kerosene; a little grit or dirt in a screw-thread or joint will make it bind, and yet it will not be secure.

Where piston-rings have been used for some time they should be replaced with new ones. If the cylinders are not

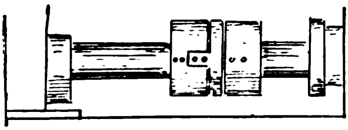


Fig. 2

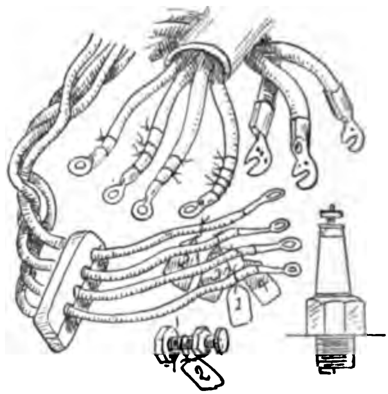


Fig. 3

worn or scored new rings of the same kind will usually answer very well, but if the cylinders are much worn or there has been much leakage by the rings the *McQuaid* or

Leakproof rings (Fig. 4) should be used. Sometimes a new top ring will be all that is necessary, but as a rule it is best to replace all the rings, and in two-cycle engines this is very essential.

In removing the rings from the pistons a good deal of care must be used, as the rings are very brittle and break easily. Of course, if you intend to use new rings it does not make much difference whether the old ones are broken or not. By spreading the rings with a pair of pliers as shown in Fig. 5, A, and placing thin brass or tin strips or old hack-saw blades between the rings and piston the rings may be slipped off very easily. New rings should be slipped on in the same way. Take off the last or lowest ring first and the others in regular order, and reverse the process when slipping on the new rings. Before placing the new rings in the grooves be sure that the latter are clean and free from caked carbon. Scrape them out to the metal, and wash thoroughly with kerosene.

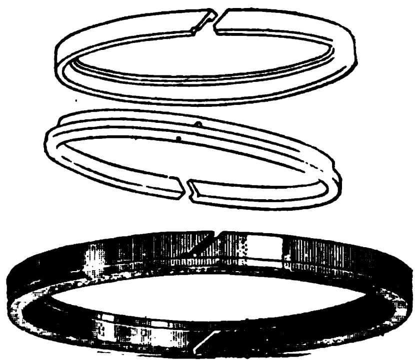


Fig. 4

You may purchase ring-spreading pliers, but you can readily rig up a pair by binding two pieces of steel rod together as shown in Fig. 5, B. You can easily determine whether or not the rings need replacing by their appearance; tight rings show a bright, polished surface all around, but leaky rings show burned or blue-black streaks and spots on their surface and on the sides of the pistons where the leakage occurs.

When you come to place the pistons in the cylinders be sure and see that the rings *break joints*—that is, that the joints on the various rings are not in line, as otherwise the

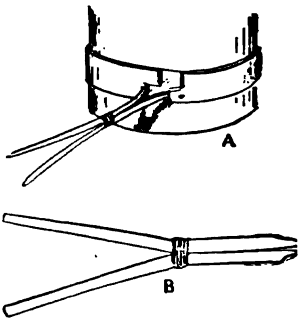


Fig. 5

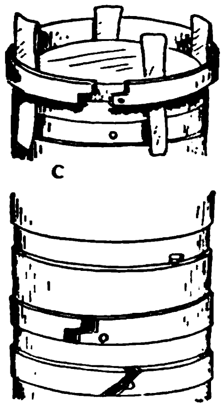


Fig. 6

gases will be sure to leak by. Most rings are pinned in position by pins in the grooves and recesses in the ring (Fig. 6). Be sure that the pins are in the proper recesses before you attempt to replace the pistons, or you will break the ends of the rings.

Always smear the inside of cylinders and the rings and pistons with thick oil or thin grease before placing the pistons in the cylinders. Most cylinders have the lower end slightly tapered or *chamfered* so that the rings slip in easily, but in cylinders with separate heads there is often a square, sharp edge, and it is very difficult to get the pistons in the cylinder when this is the case. By placing bolts or screws in the stud-holes of the cylinder and pushing wooden wedges between these and the rings the piston may be readily placed in the cylinder (Fig. 7, A). At other times strips of

brass or thin metal may be used to advantage, as shown in Fig. 7, B.

Before placing the pistons in the cylinders the latter should be scraped carefully and thoroughly to remove all old carbon, washed with kerosene, and the valves ground in. To grind in a valve is a simple and very important operation. It is first necessary to remove the valve-spring and foot. This may be done by hand on many small motors, but as a rule you will find a valve-lifter necessary. This is a tool for holding the valve in place and compressing the spring so that the cotter-pin, or key that secures the foot, may be readily extracted. There are various forms of valve-lifters, and the one you select is a matter of choice; probably the most satisfactory form for general use is that illustrated in Fig. 8, A, but the cheaper types, such as B, C, D, E, work very well.

After the spring and foot are removed lift the valve from its seat and clean the surface of the valve and its seat thoroughly. If the valve-cage is removable it is best to take it out, but if it is made in the cylinder the opening from the

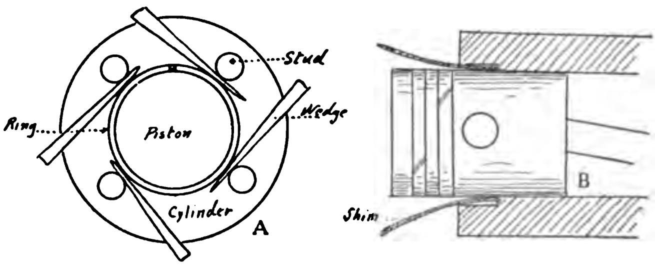


Fig. 7

valve-chamber to the cylinder should be plugged with rags or cotton waste. Now spread a thin layer of any good valve-grinding compound on the surface of the valve and place it in position on its seat. With a heavy screw-driver

inserted in the groove on top of the valve press the valve down firmly and turn it rapidly back and forth through half a revolution. As soon as the *gritty* feeling ceases lift the valve, place a little more compound on it, place in a slightly different position, and proceed as before. From time to

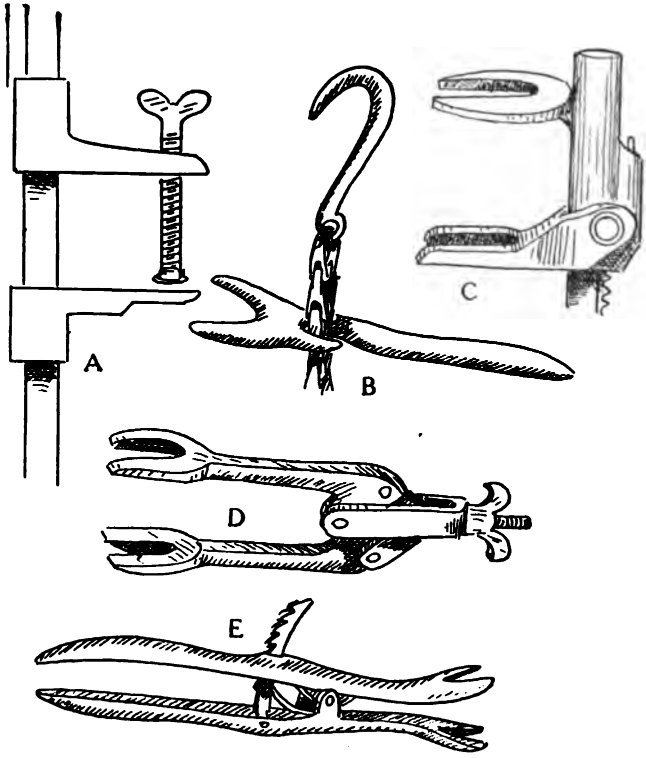


Fig. 8

time wipe off the compound and examine the surface of the valve and its seat. If it shows a bright, smooth surface all around the valve is sufficiently ground, but if there are dull spots or streaks or rough spots continue grinding until all these have disappeared. After the valve is roughly ground

it should be finished by grinding in with a very fine compound or with powdered crocus and oil until the surface shows no ridges or rings, but is smooth and even. When the grinding is completed cleanse the valve, the seat, the valve-stems, and the interior of the valve-chamber thoroughly, for if any compound is left in the interior it may work into the cylinder and score the cylinder and piston-rings.

Many valves are not furnished with a screw-driver slot in the top, but have two small round holes instead. When such valves are found a special tool must be used for grinding. Usually the tool is furnished with the motor, but a service-

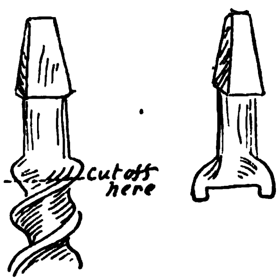


Fig. 9

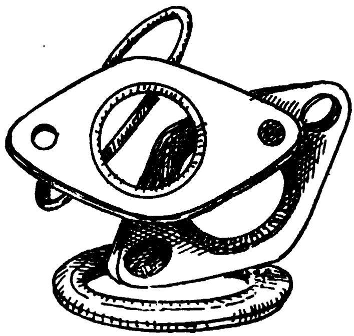


Fig. 10

able substitute may be made from an old augur-bit, as shown in Fig. 9. Valves that are newly ground in are seldom really tight until they have been run for some time, and, as grinding allows the valve to come down a little in the seat, you will have to adjust the tappets, or push-rods, to correspond. As a general thing there should be from 1/64" to 1/32" between the end of the push-rod and the valve-stem when the valves are fully closed. Many push-rods, however, have light springs which keep them pressed against the valve-foot. When this is the case you must press down the tappet,

or push-rod, and note the distance between it and the valve-foot when the spring is not holding them together.

Any of the commercial valve-grinding compounds are excellent, but if these are not on hand or cannot be obtained readily you can use fine emery and oil with equally good results.

When taking down the motor you will find various *gaskets* of asbestos, copper, etc. Around the exhaust and intake manifold are round or oblong gaskets, such as shown in Fig. 10, while under the covers to the valve-chambers and beneath the spark-plugs may be ring-like copper gaskets. These are both made of thin brass or copper, with a packing of asbestos, and they are seldom fit to use over again. It is always wisest to replace all gaskets with new ones, as they are very cheap, and a great deal of leakage and trouble may be avoided in this way.

Between the cylinders and the base, between the two halves of the crank-case, and, in fact, wherever two flat surfaces join, you will find a thin gasket of paper, felt, or asbestos. In taking the motor apart these gaskets are invariably torn or broken. Do not try to save them, but scrape off all the pieces adhering to the metal and make new gaskets. This is very easy, and insures tight joints. In making a gasket of this kind select the material to be used, lay it on the surface where it belongs, and with a small wooden mallet or *Babbitt hammer* tap all over the surface until the edges, corners, bolt and screw holes, etc., are well imprinted on the material. Then with a circular punch cut all the holes smoothly, and with a pair of scissors cut along all the edges. Before placing the gasket in place when reassembling it should be smeared with shellac and both surfaces of the metal joint should also be shellacked and the pieces fastened in position while the shellac is still wet.

In taking down or assembling a motor there is no exact order to be followed, for different motors vary in their constructive details and each must be treated in a different way. Automobile motors should be removed from the frame, or chassis, before overhauling, and the exact method of disconnecting the clutch, control-rods, wires, water-connections, exhaust, fuel-pipe, etc., will depend upon the make and design of the motor and car. Generally the first step is to remove the radiator, then the water connections and exhaust, next the wires and control-rods and fuel-pipe, then disconnect the clutch or universal joints, unfasten the bolts that secure the motor to the frame, and see that everything is clear. Fasten a strong rope or a chain around the motor near the center, and attach a block and tackle or chain-hoist overhead. Hoist slowly and watch the motor as it lifts from the frame. If it binds or catches look about and find the trouble and loosen or move the parts until the motor lifts clear off the chassis. Some motors may be lifted directly up and the car pushed back out of the way, while others must be pried or moved ahead as they are lifted in order to disengage the clutch connections. Still other motors have the transmission and motor in one casting and are very difficult to remove, but in every case you must use your own judgment or consult some one who knows how in order to remove the motor in the easiest and safest way.

After the motor is free from the car it may be placed on a rough wooden frame or support and taken down easily. In the majority of motors the first step is to remove the carbureter and magneto, marking the latter as already directed, then the spark-plugs and water-pipes or manifold, then the valve-cage caps. Disconnect any small parts, such as oil-pipes, priming-cups, fan-supports, etc., and loosen the bolts that hold the cylinders to the case. Lift the cylinders

off by hand or with a hoist, and the case with the crank, pistons, and other connected parts will be all that remains. This should then be turned upside down, the lower half taken off and the crank and bearings exposed. The end covers to the gear-case may next be removed, the gears marked, and the gears taken off if necessary. As a rule it is not essential to do this, and unless the cams or cam-shaft are loose or worn it is best not to disturb them.

In reassembling reverse the operation as far as possible. In some cases it is easier to place the cylinders on the case, place the pistons in the cylinders, and connect the shaft and connecting-rod afterward than to drop the cylinders down over the pistons. In other cases the pistons are placed in the cylinders on the bench, the cylinders then bolted to the case, and the bearings connected afterward. In most motors with two or more cylinders cast *en bloc* this is the easiest method. Still other motors have removable or separate heads, and in these the pistons are usually shoved down from the top after the cylinders and shaft are in position.

The principal thing is to watch each part as you take it down and remember how it was arranged, look over everything and consider it carefully before touching it, and use common sense at all times. If in doubt do *not* touch any part until you have studied it thoroughly or have asked some competent machinist or mechanic about it.

Chapter XV

TOOLS AND SUPPLIES

WITH the best of care and attention there are times when a motor will give out or become stalled. At such times it is most important that you should know what to do and how to do it. This is particularly true of marine motors, for, while the autoist can walk to the nearest railway or trolley line and reach his destination and send a garage man to look after his disabled machine, the motor-boatist must depend upon his own resources and must come home "under his own power" or trust to being rescued by some other craft.

No matter how much you know about a motor or how certain you may be as to the trouble, you cannot accomplish anything without tools. Many an autoist and the majority of motor-boat owners carry but a very few tools, and mighty poor ones at that.

Tools are very important, and poor, rusty, dull, or broken tools are about as bad as none at all.

For ordinary repairs that are likely to become necessary while away from the home or shop comparatively few tools are necessary, but they should be carefully selected, should be adapted to the motor, and should be kept in good, serviceable condition at all times.

Many operators of motors have a lot of tools around, but quite often the tools are entirely unsuitable for the work

when they are required. It is very irritating to discover that not a single wrench in your kit will fit a certain bolt or nut, and yet this often happens, especially where *open-end* wrenches are furnished.

In selecting the wrenches be sure and see that *every* bolt-head or nut can be reached with some wrench and that you have wrenches that will fit any bolt-head or nut on your motor. Nine times out of ten the nut or bolt that gets loose will be the one most difficult to reach.

Many motors have the screws and bolts in most inaccessible places, and it sometimes seems as if the makers purposely tried to see how difficult they could make repairs for the owners. Have several screw-drivers, and be sure that each screw can be reached with some of them.

Avoid end-wrenches as far as possible, and in their place use the various adjustable forms.

It is useless to duplicate tools; if there are two or three wrenches just alike there will always be confusion and just so much more to care for.

The most important tools for ordinary motors are as follows, but some motors require special tools which must either be made to order or obtained from the makers of the engine.

A *Stilson* or pipe wrench capable of handling any pipe on the motor. Usually at least two Stilson wrenches are required—one for the small pipes and another for the larger ones.

A *Coe* or monkey wrench large enough to handle the largest nuts or unions on the motor, and a medium-sized Coe for small nuts. In addition you should have a very small monkey-wrench or bicycle-wrench for small nuts.

A medium-sized—about six or eight inch—*Westcott* or adjustable *S* wrench.

A pair of combination cutting-pliers and tweezers.

A pair of round-nosed pliers.

An assortment of screw-drivers with short, medium, and long handles.

A medium-sized machinist's hammer with round pein.
A cold-chisel (about 1/2").
A *cape*-chisel of 1/4", and also a small *diamond-point* chisel.
A center or *prick* punch.
A hollow-end punch.
Flat, half-round, round, and three-cornered files.
A *valve-lifter* if the motor is a four-cycle.
An *ammeter* for testing batteries.

In addition to the tools you should *always* be supplied with a few extra parts and a reasonable assortment of nuts, screws, bolts, etc. In selecting these go over the motor carefully and make a list of the various sizes of nuts, screws, etc., and purchase duplicates of each. Such things are very cheap and you may never require them, but threads *will* become worn and stripped, springs will break, and nuts will become loose, and I have seen a machine helplessly held up for hours for the want of an ordinary 3/8" bolt.

The "extras" that are usually most important are the following:

An assortment of copper and iron wire of various sizes.
Extra insulated wire, both primary and secondary.
Extra valve-springs.
Extra spark-plug connections and terminals.
Extra spark-plugs.
A small box of assorted *cotter-pins*.
A box of assorted *lock-washers*.
Various machine-screws, cap-screws, nuts, and washers.
A supply of prepared solder, such as *Solderal* or some similar make.
Extra spark-plug and manifold gaskets.
A roll of adhesive tape.
If the motor has any small or delicate parts, as is often the case in make-and-break motors, a full set of these parts should be carried.

With the above tools kept in good condition and with the various spare parts on hand a breakdown will hardly ever occur which cannot be repaired in a short time. If you are going on a long auto tour or you have a cruising power-boat

you should also have various other tools, such as a small vise, a breast-drill with assorted drills, a bit-stock with various twist-drills, reamers, etc., a hack-saw frame and blades, machine taps and dies, calipers, and a set of ratchet socket-wrenches. As these tools are essential in a garage or shop, they may be used in such places and taken along on extended tours or cruises.

Handy Hints and Emergency Repairs

Even with a splendid assortment of tools and parts there are many motor-operators who would still be perfectly helpless if anything happened. The proper use of tools and a knowledge of the best and quickest way to accomplish a repair are nearly as important as the tools with which to work.

You must not expect to work metal as readily as wood, even with the finest hand-tools, and many a man does more damage to tools and parts in a few moments trying to force things than can be repaired in several hours.

Slowly and surely is the way to work metal or handle obstinate bolts and nuts. Trying to drill too rapidly will result in broken drills, and if a piece of the drill sticks in the hole it will require much time and labor to remove it, even if it can be accomplished without resource to a machine-shop. If you use too much force on a bolt or nut that is rusty or stuck you may strip the threads or break off the bolt. If you do this once and are obliged to drill out the old bolt and rethread the hole by hand you will never again attempt to force a small stud with a large wrench. Usually a slight tap with a hammer will start a nut or joint, but wherever the surface to be struck joins another surface or is threaded you should always place a hard-wood billet or a piece of

copper, brass, or aluminum over the spot and strike this with the hammer. For such purposes a copper or Babbitt-hammer is splendid, and I advise every motor-owner to have one in his kit. Great care should always be used when striking cast iron, for the high-grade iron used in motor construction is almost as brittle as glass. Very frequently an obstinate bolt or nut may be started by tapping the wrench-handle when a steady pressure will not start it. If the bolt or nut is inaccessible or there is little space in which to move a wrench it may be started by a cold-chisel and hammer, but this is not ordinarily advisable, as it scars the bolt-head or nut and may *shear off* a corner. Turpentine is very useful in starting rusty bolts, etc., and makes drilling, filing, or sawing metal very easy. Many tight or rusty joints in pipes, screw-threads, etc., will separate easily if soaked a short time in turpentine. Kerosene is also excellent for this purpose, but the best material to use is *lime-oil.* A drop or two of this extract of the well-known fruit will penetrate to every crack and crevice, and an exceedingly rusty screw or bolt will often come away easily if treated with lime-oil.

At times the joints become so badly corroded that more severe measures must be resorted to. In such cases wrap the joint with a rag dipped in kerosene, turpentine, or gasoline and ignite it. When burned out and while the joint is still hot try the wrench on it.

I have already spoken of broken bolts and the trouble incurred in drilling them out. Many times this can be avoided by boring a small hole in the broken stub and tapping it with a left-handed thread. Then by screwing a left-handed screw or bolt into this the old stub may be unscrewed.

A bolt or screw-thread often becomes so worn, rusted, or

loose that it will not hold. If no new part is on hand the old one may be made to hold fairly well by slitting the end of the bolt or screw and spreading the sides slightly (Fig. 1, A). In the case of large bolts a small wedge may be driven in the slot (Fig. 1, B). If the nut is worn and the bolt is in

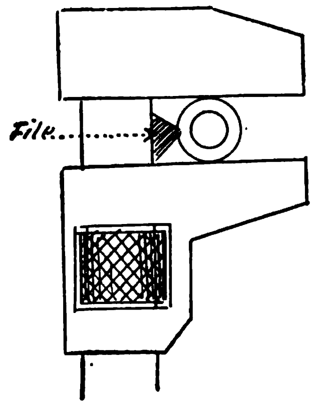


Fig. 3 A

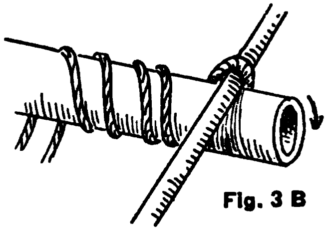


Fig. 3 B

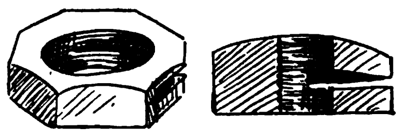


Fig. 1 C

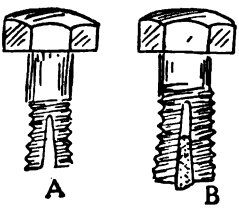


Fig. 1

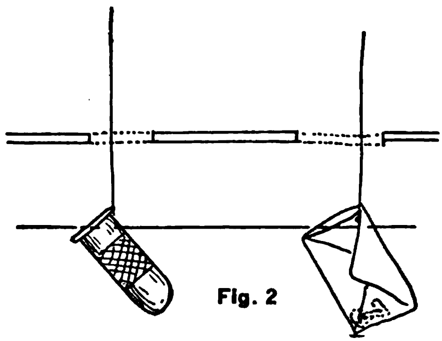


Fig. 2

good condition the former may be tightened by heating it red-hot and then sprinkling the outer edges with cold water. This will shrink the nut and result in a snug fit. The use of heat is very important about motors, for many joints which cannot be taken apart or put together properly when

cold may be separated or made tight by judiciously heating them. Loose sprockets, cams, wheels, etc., can be made very tight by expanding the parts with heat and while still hot placing them in position and allowing them to shrink to a tight fit.

While every nut should be secured with a cotter-pin or a lock-washer, or both, this detail is frequently overlooked, and a nut may become loosened by vibration. This trouble may be easily overcome by sawing a slit a little less than half way through the nut and then springing it together as shown in Fig. 1, C. A nut thus treated will never loosen, but you should be careful not to cut the slit too wide or too deep, or the threads may be stripped in setting it up.

Where pipes are used you may now and then have occasion to use a fitting of a larger or smaller size. If no bushing or reducer is at hand and you have pipe-thread dies and stocks you can readily make excellent reducers with pieces of brass pipe. Each size of brass pipe will thread inside for the next smaller size. Thus 1″ will thread for 3/4″, 3/4″ will thread to 1/2″, and so on. Iron pipe will not thread so well, but in many cases a thread can be cut inside an iron pipe which will answer temporarily. Pipe couplings threaded on the *outside* may be used as reducers also, but they are difficult to thread and are not as good as the pieces of brass pipe.

Where a joint in a pipe or a bolt in a hole becomes loose from jar or vibration and a permanent joint is required it may be cemented together by using a strong solution of sal-ammoniac and water and the joint left undisturbed for a few days. This mixture will often heal up a crack or small hole in a leaky water-jacket or pipe. If the joint to be cemented is very loose or large a mixture of sal-ammoniac 4 parts, sulphur flowers 2 parts, and iron filings 32 parts

mixed to a paste with water may be used. This cement will also fill up fairly large cracks or holes. Glycerine and litharge also forms a very hard, tenacious, and water and fire-proof cement which is useful in many places.

Joints that become leaky in water-pipes may be temporarily stopped by winding with adhesive tape, or even with a greasy rag or cloth. A splendid cement for stopping water leaks is ordinary chewing-gum thoroughly masticated. Place a piece of the gum over the hole or crack, wrap it with strips of cloth, string, or adhesive tape, and you will have a perfectly tight repair which will last a long time. I have seen a hole in a water-tank patched in this manner which outlasted the rest of the tank and was perfectly tight after two years use.

Fuel-pipes will often leak from continual vibration, and they should be rebrazed or soldered when this occurs. If no soldering appliances are available the leak may be stopped by wrapping with rags or paper dipped in shellac, or a wad of ordinary soap may be plastered around the leaky joint and held in place by rags or string. Never use adhesive tape on a fuel-pipe; gasoline destroys it in a few moments.

If you are on an automobile trip and a soldered connection becomes loose or broken you can mend it by heating it in the flame of one of the gas or acetylene head-lights, but if you are always provided with a stick of one of the prepared solders you can make a soldered connection with an ordinary candle or even a match.

It often happens that you may require a small quantity of gasoline for priming or similar purposes. Most automobile and boat tanks have a cock for drawing off the fuel, but sometimes this is not furnished or is in an inaccessible spot. At such times the desired quantity of gasoline may be

obtained by using an old envelope or the valve cap to an auto tire. To use the envelope drop a nut, bolt, screw, or other heavy object in it, fasten a string to one corner, and lower it into the tank through the filler hole. The weight in the envelope will sink it in the gasoline, and as this substance does not soften or dissolve the gum or paper as does water, there will be but little leakage when you draw the envelope up.

When the filler hole is too small to admit the envelope the latter may be folded lengthwise or pinned or tied together and used in this shape.

In using a valve-cap it is only necessary to fasten a string or wire to the upper or open end of the cap, lower it through the filler hole in the tank, and draw up the cap full of fuel like a miniature well-bucket (Fig. 2). If you should require a pipe-wrench and have none in your kit there are several methods by which you can hold a pipe very firmly without a regular pipe-wrench. By placing a three-cornered file in a monkey-wrench and placing the pipe in this you can hold it firmly (Fig. 3 A). Another method is to wrap the pipe, in the direction it is to be turned, with a small rope or strong cord doubled. A stick or bar is placed in the loop at the end and used as a lever. One hand should hold the cord in place and the other should be used to turn the bar. If the rope slips it may be dampened with water (Fig. 3 B).

If you use a file for lead, copper, aluminum, or other soft metals it will soon become clogged and will not cut. Files thus dulled may be cleaned and made as good as new by soaking for a short time in sulphuric acid and water. A weak solution—about one ounce of acid to two quarts of water—should be used, and after soaking a few hours the files should be thoroughly washed in a strong soda solution, brushed

clean with a stiff brush, and dried by heat, after which they should be well oiled.

Clogging may also be avoided by rubbing the files with chalk before using them on soft metal.

Aside from these few hints on short cuts and emergency repairs there are a vast number of easy ways and *kinks* which every motor-owner will find out for himself as occasion arises; a little ingenuity and some inventive ability are mighty useful assets when tinkering around a gas engine.

It is far easier to prevent troubles than to repair them, no matter how ingenious you may be, and to do this you must be thoroughly familiar with your motor and must understand its ways and needs.

By studying the illustrations and descriptions in the foregoing chapters you should be able to master the principles, use, and care of any gasoline motor, and with the knowledge thus obtained you will find added pleasure and satisfaction in operating a motor, motor boat or car.

APPENDIX

Appendix

MOTOR TROUBLES AND THEIR REMEDIES

AS there are a vast number of things which *may* happen to a motor, and as each particular brand of motor has ills and misfortunes peculiar to its kind, it is impossible to enumerate every trouble which may crop up. The majority of the troubles are seldom encountered unless a motor is neglected, and the troubles that are likely to occur are comparatively few in number, are easily located, and can usually be remedied with little labor or expense if attended to promptly.

In the following table the more important and common troubles are enumerated, with their causes and the methods of remedying them.

Troubles are usually indicated by some certain symptom or noise, and the person familiar with motors can judge of the trouble and locate it by these symptoms, just as a physician can diagnose a disease or injury by the symptoms of the patient.

For this reason the symptoms should come first, and in the table these have been arranged in alphabetical order, with the trouble and remedy following. Sometimes various troubles may be indicated by symptoms which are almost identical, and in such cases you may be obliged to try several remedies before you cure the trouble. Even the best doctors are often at a loss to definitely name a human ailment, and if this is the case with a patient who can talk you should not be discouraged if you occasionally make a mistake when treating your dumb motor-patient.

TABLE OF TROUBLES AND THEIR REMEDIES

SYMPTOM	TROUBLE	REMEDY
Air-lock. Circulation poor. Motor heats.	Air in water-pipes. Pump broken or stuck. Leak in pipe or pump. Belt-drive to pump or fan slips. Check-valves clogged.	Search for and repair all leaky joints. Prime the pump with water and pour water in through pipes. Clean the pump check-valves or strainer and tighten belt.
Back Explosion. Pre-ignition, or kicking back, when starting or stopping. Pounding of motor. Motor may start backward. Loud explosions in muffler.	Spark too far advanced. Overheated engine. Too much oil or gasoline. Carbon in cylinders. Thin "fin" of metal or end of screw in cylinders. Spark-plug points too thin or dirty. Short circuit in breaker or timer. Valves out of time.	Retard spark. See that cooling system is in proper condition. Clean out carbon. Feed less oil or gas. Try new plugs or clean old ones. Clean timer and try new wires. Test valve adjustment.
Bad smell from exhaust.	(*See* Lubrication and Overheating.)	
Batteries not working properly. Sluggish action of motor. Misfires. Engine stops, and after standing will start easily, but soon misses.	Old or wet batteries. Two batteries or two connections in contact. Wires or connectors loose or broken. Spark-plug broken, short-circuited, points too far apart or too close together. Vibrator of coil worn, pitted, or stuck. Make-and-break parts worn, stuck, or dirty. Weak spring on make-and-break. Cracked porcelain in plug. Flooded cylinder.	Test batteries and try new ones. Place rubber or wood under and between batteries. Go over wires, tighten connections, and put in new wires where worn, wet, or greasy. Try a new plug. Adjust and clean vibrator or breaker-points. Test various parts of make-and-break system by hand. Try new springs. Drain excess fuel from motor-base and try with relief-cock open.
Bearings squeak, pound, jar, shake, heat, seize, or rattle. Engine turns hard. Sluggish operation.	Bearings too loose, too tight, dirty, improperly oiled, wet, worn, or motor overheated. Connecting-rods bent or shaft out of line.	Lubricate thoroughly. Tighten or loosen bearings. Clean with kerosene. Replace old bearings with new. Examine cooling-system and feel of bearings when running.
Black smoke from exhaust. **Blue smoke from exhaust.**	(*See* Loss of Power, Overheating, Flare-up, Popping.)	

APPENDIX

SYMPTOM	TROUBLE	REMEDY
Blow-back. Popping noise at carbureter. Explosion or flame in carbureter. Pound. Knock. Loss of power. Blue smoke. Hard starting.	Worn or pitted inlet-valves. Check-valve in carbureter broken or weak. Dirt or water in gasoline. Needle-valve stuck. Float-valve stuck or float loose. Float set too low. Fuel-tank too near level of motor. Too much air. Too little fuel. Poor timer or magneto adjustment. Intake-valve too tight or out of time.	Regrind and clean the valves. Renew valve-springs and adjust push-rods. Test for valve-timing. Adjust carbureter and timer. Clean carbureter, tank, and fuel-pipes. Examine float. Place tank higher, or attach a pressure pump.
Boiling.	(*See* Overheating.)	
Buzzing.	(*See* Coil.)	
Carbureter. Sluggish operation. Poor or irregular action. Flooding carbureter. Motor overheats. Pounding. Backfiring. Bad odor. Blue or black smoke.	Gasoline supply low. Fuel-pipe choked or too small. Dirt or water in carbureter. Needle-valve bent or worn. Float-valve stuck, dirty, worn, or badly set. Valves stuck. Air-intake choked. Poor or stale gasoline. Carbon in intake or exhaust. Carbureter adjustment poor.	Try flow of fuel by disconnecting pipe. Blow back through pipe. Drain fuel from tank and carbureter. Examine float and needle valve. Try new spring on air and check valves. Try different adjustment. Clean out carbon.
Circulation poor.	(*See* Air-lock and Overheating.)	
Coil buzzes weakly or irregularly. Bright sparks at points. Buzzes inside of box. Buzzes when timer is not in contact or when switch is off.	Vibrator-points worn, dirty, or pitted. Wrong adjustment. Weak batteries. Short circuit. Vibrator-spring too weak or too strong. Coil punctured, wet, or burned out. Insulation broken. Timer or breaker-box dry or "glazed" or badly worn. Loose strand of wire touching some metal.	Clean and file the contact-points smooth. Try various adjustments. Test coil and batteries for amperage. Try motor with another coil. Overhaul all wires and connections. Clean and oil timer or breaker.

SYMPTOM	TROUBLE	REMEDY
Compression poor or leaky. Engine has little power and turns easily past compression. Hissing sound when motor is turned by hand. Hard to start. Misfires. Overheats in base.	Valves stuck, worn, pitted, dirty, or springs too weak. Badly adjusted push-rods. Cracks in cylinder. Poor gaskets somewhere. Rings worn, broken, or stuck. Ring-joints in line. Spark-plugs loose, thread worn, or porcelain cracked. Priming or relief cup loose, worn, or stuck partly open. In make-and-break motors bushings around igniter worn or main bearings worn. Scored cylinders.	Examine, clean, and grind the valves. Clean off their stems and try new springs. Place new gaskets on joints. Try new plugs and cocks. Try new piston-rings. Use new bushings or bearings. Find the leak by squirting soapsuds around joints until bubbles indicate leak.
Compression entirely fails. Motor will not start. Wheel turns freely through entire revolution.	Valve or governor stuck or broken. Cam, push-rod, or gears stuck or broken. Cracked or broken cylinder. Badly broken rings. Broken piston. Connecting-rod bearing broken. Crank-shaft broken.	Take motor down and examine all internal parts, but first look for broken or stuck valves or push-rods.
Compression too great. Hard to turn motor over. Hard to start. Will run idle, but will not carry load. Will turn a few turns one way and reverse. Will stop on part of revolution.	Not a true compression trouble. Piston binds or sticks at one spot. Ring broken or out of groove. Piston-pin or connecting-rod bearing worn or rod out of line. Bent shaft or broken bearing. Bearings too tight or stuffing-box on boat too tight. Universal joint stuck or broken. Some part out of line. Piston strikes shoulder on top of cylinder or spark-plug is too long. Some broken part on top of piston. Carbon in cylinder near end of stroke. Lack of lubrication. Too much friction somewhere.	Detach motor from drive-shaft. If operation is all right trouble is not in motor. Clean piston and cylinder. Oil thoroughly. Adjust all the bearings. Loosen motor from bed and try it with a little play on bed-plate. Run kerosene through cylinder and lubricate. Loosen up each bearing in turn. Take down motor and examine interior.

SYMPTOM	TROUBLE	REMEDY
Connecting-rod pounds or knocks. Loud clanging noises. Sudden stoppage. Pound.	Preignition. Cylinders badly timed or wires led to wrong cylinders. Valves out of time. Reversing too suddenly. Spark too far advanced. Mixture wrong. Broken piston, rings, bearings, crank or connecting-rod, or piston-pin. Worn, cracked, burned-out, or loose bearings. Lack of oil. Water in cylinder. Water in base. Piston striking some portion of inside of engine. Loose set-screw in piston-pin. Carbon in cylinder.	Retard spark. Try a different mixture. Drain cylinder base. Examine plug for signs of water. See if steam issues from exhaust. If symptoms of water appear place new gasket under cylinder-head. Try new relief-cocks. Examine jacket for crack. Lubricate thoroughly. Scrape out carbon. Try turning motor by hand slowly to locate knock. Examine bearings, pistons, cylinder, and other parts.
Crank-shaft.	(*See* Connecting-rod, Pound, Knock, etc.)	
Cylinder pounds or knocks. Loss of power. Misfires. Loss of water. Steam from exhaust. Too much vibration.	Crack in cylinder or jacket. Leak around packing in head. Porous iron in casting. Blow-holes in casting. Leaks around cocks or connections. Scored cylinder. Stuck ring. Loose piston-pin. Carbon. Loose piece of metal in cylinder. Cracked piston. Pump-gland striking eccentric rod when plunger-pump is used. Preignition. Poor lubrication. Loose or worn cams or tappet-rods. Push-rods too long. Loose fly-wheel. Loose bearings. Cylinders loose on crank-case.	Proceed as in the last and locate trouble by trying each part. First lubricate thoroughly and clean out the carbon. Tighten up on all bolts and nuts. Tighten fly-wheel. Adjust push-rods. A small pound or knock is *very* hard to locate.
Explosions in muffler, base, or carbureter.	(*See* Backfiring, Blow-back, Flare-up, Knocking, Misfires, Mufflers, Timer Troubles, etc.)	
Failure to Start.	(*See* Water, Compression, Short Circuits, etc.)	

SYMPTOM	TROUBLE	REMEDY
Firing in carbureter, base, muffler, etc.	(*See* Flare-up, Back-firing, Blow-back, Misfires, Mufflers, etc.)	
Flame in carbureter.	(Same as above.)	
Flare-up. Flame at carbureter or intake manifold. Popping noise or blue smoke around carbureter. Back-explosions.	Leak in pipe line with short circuit, causing spark that ignites free gasoline. Poor or weak mixture. Gasoline in base. Valve or spring stuck, thus letting burning gas blow back.	Very dangerous and easily located and remedied.
Flooding.	(*See* Carbureter.)	
Gear seizes, slips, jerks, grates, or groans.	Worn or loose gears. Water or dirt in gears. Gear-case loose or dirty. No grease in gears. Wrong adjustment. Broken tooth in gear. Loose key or bushing. Loose set-screw. Broken ball in bearing. Gear out of line.	Fill gear-case with a heavier grease. Overhaul gears and clean. If worn, loose, or broken, the parts should be replaced with new ones.
Governor fails to act. Engine races, stops, runs unevenly. No compression. Picks up slowly.	Springs on governor too strong or too weak. Governor dirty, stuck, or corroded. Looseness somewhere.	Clean thoroughly, remove old oil or paint. Try new springs and see that parts move smoothly and easily.
Grinding Sounds.	(*See* Gear.)	
Ignition faulty. Motor runs jerkily, sluggishly, or unevenly. Starts hard. Will fire priming charge but will not run. Misfires. Back-explosions. Muffler explosions. Pound.	Short circuits. Weak batteries. Breaker out of adjustment. Coil burned out or vibrator-points in bad shape. Ignition too early or too late. Timer dry, dirty, or worn. Timer contacts do not meet. Wires broken, loose, or bad insulation. Magneto slips. Oil, soot, or water on plugs. Porcelains or mica broken or dirty. Battery or other connections loose, corroded, dirty, or wet. Switch contacts poor. In make-and-break the contacts of igniter may be pitted, dirty, rusty, or springs may be too weak.	Overhaul wires and all ignition devices. Test batteries and coil. Clean vibrator-points. Try new plugs, timer, etc. File ends of igniter smooth. Try new springs. Test each spark-plug by laying it on cylinder and turning motor to firing-point. Remember that nine-tenths of all troubles are due to ignition.

APPENDIX

SYMPTOM	TROUBLE	REMEDY
Knock or pound. Any unusual sound or rattle. Occasional loud explosions in base or smoke blowing through joints in crank-case.	Preignition. Spark advanced too far. Carbon in cylinder. Short circuits. Poor lubrication. Poor water circulation. Bad mixture. Loose, worn, or broken parts. Some moving part striking against another. Choked muffler or exhaust. Exhaust-pipe too small. Water in cylinder or base.	Overhaul ignition and lubricate thoroughly. Examine water circulation. Try different carbureter adjustment. Drain and clean carbureter and tank. Try new spring in carbureter check-valve. Clean inlet-valve. Use heavier oil. Clean out carbon. Examine for loose bearings or broken parts. Retard ignition. Disconnect muffler and try with it off.
Loss of power or poor speed. Sluggish running. Misfires. Back-explosions. Smoke from base or through carbureter. Blue smoke from exhaust. Fails to run well, but starts easily.	Poor ignition or fuel mixture. Faulty lubrication. Too much air or too little gasoline causes base explosions. Too much fuel or too little air causes black smoke, bad smells, and misfires. Too much oil gives blue smoke. Failure to run after starting shows too rich a mixture or a stoppage of fuel-supply. If motor runs well at one speed but misses when slowed down or opened up the mixture is wrong. If it backfires it is too weak. If it chokes it is too rich. In two-cycle motors the base joints may leak or check-valve in carbureter may fail to seat properly.	Look over ignition. Try new fuel adjustment. Drain and clean the carbureter. Try new spring in check-valve. Use heavier oil. Advance or retard the spark. Adjust the carbureter when under load, not when idle.

SYMPTOM	TROUBLE	REMEDY
Lubrication poor or intermittent. Overheating. Pounding. Sluggish action. Bad odors. Misfires. Blue smoke. Seizing noise. Hot bearings.	Poor oil or an improper grade. Forgetting to oil or oil not feeding. Choked oil-pipes or oilers. Oil-pump not working. Grit or dirt in oil. Leak in oiler-tank. Too much or too little oil.	Try a different grade of oil, and thoroughly clean all pipes, oilers, feeds, and connections with kerosene. Adjust feeds carefully. See that pump is working. Test tank for leakage. Use the *best* oil that money can buy—oil is cheaper than engines.
Misfires. Engine runs badly, unevenly, and will not show full power. Base or muffler explosions. Bad odors. Hard to start. Knocks or pounds. Kicks back.	Ignition or carbureter troubles usually. Dirty, cracked, or broken plugs. Points too far apart or too near together. Breaker or timer dirty, worn, dry, or not making good contact. Brushes of magneto worn or stuck. Wire connections corroded, dirty, or loose. If engine runs slower and slower and finally stops the mixture is too rich or batteries are run down. Carbureter adjustment may be wrong. Throttle or needle-valve shakes shut. Float leaks or is too high or too low. Igniter on make-and-break is gummed or springs not strong enough. Wire may be broken, loose, or may rub against another wire. Coil may need adjusting.	Overhaul ignition as usual. Try new switch, wire, and battery connections. Oil and clean timer. Use new batteries. See that magneto-drive is not slipping. Try various carbureter adjustments. See that air-vent in tank is clear. Tighten nuts on throttle and needle-valve. Put new brushes and springs in magneto. If you use both magneto and batteries try first on one and then the other until trouble is located. Go over wires carefully, and if necessary try new ones. See that valves are properly timed and adjusted. Be sure that a cam is not loose. Clean igniter parts, and oil slightly.
Muffler troubles. Loud explosions. Does not quiet exhaust. Noises. Rattles. Hissing sounds.	Unexploded gas entering muffler and ignited by heat of same or by next burning charge of gas. Muffler choked, or too rich a mixture. Muffler loose, broken, or cracked. Misfires Poor ignition or leaky valves.	Slow motor down before stopping. Shut off by throttle instead of by switch. Use water-cooled exhaust or muffler. Use larger exhaust-pipe or muffler. Clean muffler. Tighten up muffler and exhaust connections. Use weaker mixture. Adjust valves and ignition devices.

APPENDIX

SYMPTOM	TROUBLE	REMEDY
Noises and rattle around engine.	Loose nuts, bolts, or small parts or slightly loose bearings. Loose piston-pin. Loose cylinder. Loose or poorly lubricated gears. Loose pump-gears or pump-paddles. Valves, valve-guides, push-rods, or push-rod guides worn or loose. Too much space between tappets and valve-stems. Loose cam-shaft. Loose cams. Poor springs or springs too weak. Loose crank or crank striking end of shaft. Loose universal joints or portion of clutch mechanism. Some part bent, cracked, or broken. In make-and-break motors usually due to loose or worn igniter parts.	Tighten up all nuts, bolts, screws, and connect. Hold a piece of wood or your hand on various parts to determine where noise originates. Oil well, and use heavy grease in gear-case. Place fiber washer under springs and in any place where two pieces of metal strike together. Adjust tappets and valve-stems closely. Take up all lost motion. Throw out clutch, and if noise ceases the trouble is not in engine. Usually easy to locate and remedy.
Overheating. Smells of burning oil or paint. Water steams or boils. Pounding. Clanking noises. Jerky motion. Engine slows down and stops. Will continue to fire after electricity is shut off.	Defect in water circulation or in cooling system. Choked or air-locked pipes. Dirty radiator. Collapsed rubber hose or loose piece of hose lining. Pump broken, jammed, or stuck. Packing of pump leaking. Leak in pipes or pump, allowing air to be drawn in. Check-valves in water-pipes stuck or dirty. Bits of foreign substance under valve-seats. Too rich a mixture. Poor lubrication. Retarded spark. Not enough lift to exhaust-valve. Valves badly timed. Not enough water. Pump too small. Racing engine. Running a long time on low gear. Fan inefficient or belt broken or slipping.	Clean radiator and all pipes by filling with strong sal-soda solution and flushing out. Put on new hose connections. Examine pump and drive and test by disconnecting a pipe leading from it. Put new packing around spindle and see that there are no leaks in pipes. Examine all water-pipe valves. Use a new exhaust-valve with longer stem or adjust tappets to give more lift. Cut down on fuel. Use more or lighter oil. If a marine motor force air back through water intake by blowing through it, a piece of weed or mud may have choked the intake. When a motor overheats never throw cold water on it or fill radiator with cold water until the motor is cool. Advance spark, and in winter be sure that some pipe or the radiator is not frozen.

SYMPTOM	TROUBLE	REMEDY
Piston troubles. Pounds. Engine stops or is hard to start. Difficult to turn motor over. Piston seizes or binds. Squeaks, grinds.	Poor lubrication. Overheating. Piston-rings broken or stuck in grooves. Cylinder scored. Piston-pin loose and binding on cylinder. Carbon on piston. Grit or rust in cylinder. Connecting-rod or piston-pin bearings stuck or too tight. Rods or bearings out of line. Connecting-rod bent.	Clean cylinder and piston with kerosene and oil well. Examine rings, bearings, etc. Clean the grooves for the rings. Look for scored spots in cylinders. Clean out carbon. If cylinders are scored have them reground and new pistons and rings fitted. Try loosening bearings.
Popping noises in carbureter. Flame or smoke from carbureter or base. Flooding or overflowing of carbureter. Misfires. Starts hard. Loss of power.	Too much or too little gasoline. Inlet-valve stuck, worn, dirty, or spring too weak. Spark too much advanced or retarded. Float or needle valve in carbureter loose, stuck, dirty, or badly adjusted. Air in fuel-pipes. Pipes too small. Tank not high enough. Leak in intake-pipe between carbureter and motor. Valves badly timed.	Adjust mixture. Examine carbureter. Clean and drain carbureter, tank, and pipes. Examine and test valves. Advance or retard spark. Try a new float, or readjust old one. Regrind valves. Try new valve-springs. Raise tank or use pressure. This is a common trouble on motors with automatic intake or air valves or with poor or cheap carbureters.
Shocks when touching switch or engine.	Short circuit somewhere.	
Short Circuits. Misfires. Shocks from switch. Sparks at timer, on wires, or at switch. Engine stops suddenly.	Short circuits, broken or loose wires. Loose, dirty, or corroded connections. Batteries or wires touching. Breaker does not separate. Worn vibrator-points sticking. Some object across two wires. Insulation wet, oily, or imperfect. Dirty or dry timer. Wet plugs or cracked porcelains. Two wires under one staple. A fine strand of wire touching some "ground."	Go over every wire, connection, and terminal carefully. Try new plugs, wires, and batteries. Remove any staples and wrap bad spots of wire with tape. Operate motor in the dark and watch for sparks. If plugs are wet clean them thoroughly, fill end with gasoline, and ignite. Clean and oil timer. Adjust breaker. Examine brushes of magneto. If you have both magneto and battery you can locate the trouble in one or the other system by alternately operating on one and then the other.

APPENDIX

SYMPTOM	TROUBLE	REMEDY
Sparks at timer, on wires, or at switch.	(*See* Short Circuits or Misfires.)	
Spark-plug troubles. Short circuits. Misfires. Leakage around plug.	Unsuitable plug. Plug too short or too long. Points dirty or badly adjusted. Wet plugs. Rusty points. Cracked porcelain. Thread stripped. Terminal loose. Carbon in plug. Too much oil. Packing blown out or broken. No gasket under plug. Rust or oil between thread of plug and cylinder walls.	Clean and examine plug. Use a plug long enough to reach well into cylinder, but not so long that it will strike piston or valves. Have the thread on plug and in cylinder clean. Use a new gasket under plug. See that connections are bright, clean, and tight. If porcelain is cracked or plug is injured get a new plug. Adjust points so they are about 1/32" to 1/64" apart. Have new plugs on hand, and as soon as trouble occurs put a new one in. The old one may be repaired or cleaned at your leisure. If plugs show a lot of wet oil, feed less oil.
Timer troubles. Knocking or pounding. Loss of power or speed. Jerky or irregular firing. Overheating. Backfiring. Hard starting. Explosions in muffler.	Badly worn timer or fiber insulation ring. Weak timer arm-springs. Timer dirty, dry, and glazed. Fine particles of dirt, metal, or dust in timer. Short-circuiting of terminals on timer. Grease or water-soaked insulation. Timer loose on shaft. Timer-gear loose or worn or out of time. Wires led to wrong connections. Timer control-rods bent, broken, or loose. Too weak or too rich a mixture. Valves out of time or adjustment.	Clean and oil timer. Make new and clean connections. Wash off old grease and dirt with gasoline. Adjust so that contact is made at proper time. Tighten up any looseness. Look over wires, rods, gears, etc. Try new springs and adjust mixture and valves carefully. Replace old or worn fiber with new.

SYMPTOM	TROUBLE	REMEDY
Valves. Slow action. Loss of compression. Misfires. Sluggish running. Loss of power. Noisy exhaust. Blow-backs. Light knocking.	Sooty or gummy oil on the valve-stems, causing them to stick in guides. Spindles bent, scarred, or rough. Springs too strong or too weak. Pitted, dirty, worn, or scored valves or seats. Wrong timing or poor adjustment of tappets or push-rods. Too much play in rocker-arms. Cams loose or worn. Valve-gears worn, loose, broken, or wrongly set. Hole for cotter-pin in valve-stem worn oblong. In case of an automatic valve, a spring too stiff, or a leak in the cylinder, preventing suction from opening valve.	Clean the valve-stems with kerosene, and if bent or scored or badly worn get new valves. Regrind valves and place new springs on them. See that all lost motion is taken up. Leave about 1/64" between tappets and valve-stems. Test the valves for correct timing.
Water in crank-chamber, in carbureter, or in cylinder. Loud explosions. Steam from exhaust. Slow or irregular running. Hard starting. Backfiring. Water on spark-plug points. Rust in cylinder.	Leaky joints in gaskets where there is a separate head. Leakage around pet-cocks or plugs. Water in gasoline or oil. Some cock left open on a damp or rainy day or night. Cracked or broken gaskets, valve-chambers, or other parts where water circulates. Spongy or porous cylinders. Water may also get into the carbureter from rain or waves, or may condense on the inside of tank, carbureter, or base in damp or foggy weather. When running, the evaporation causes intense cold on the carbureter, and the moisture which condenses on the metal may be drawn into the cylinder or base.	Provide a strainer in the fuel-pipe. Strain all fuel through chamois before filling tank. Protect tank, carbureter, and motor from rain. Drain base of motor and carbureter thoroughly. Examine cylinder for leaks by filling jacket with water and looking inside of cylinder when head is removed. Put new gaskets on all joints where the water-jacket joins another part. Wipe off the carbureter when water collects on it or, better still, run a hot-water or hot-air pipe to it. Most carbureters are furnished with jackets for this purpose.

GLOSSARY OF TECHNICAL TERMS

A

Accelerator. Any attachment or device for increasing speed.

Advanced Spark. A spark produced to ignite a charge of gas before the piston of the motor reaches the upward limit of its compression-stroke.

Air-lock. Air which gathers in a pipe and prevents the flow of liquid.

Ampere. An electrical unit of measurement corresponding to quantity.

Ampmeter or **Ammeter.** An instrument for determining the number of amperes flowing through an electrical circuit.

Annular. In the form of a ring.

Annular Bearing. A bearing of ring shape.

Armature. A wire wound in a coil around an iron core and used in producing an electrical current between two magnets.

Atmosphere. The pressure or weight of the air, equivalent to a pressure of 15 pounds to the square inch.

B

Babbitt. A composition of various metals used in making bearings and designed to reduce friction. Bearings made from babbitt.

Back-firing. The premature explosion of gas in a gas engine, especially when the explosion takes place before the intake-valve is closed, thus causing flame or smoke to issue from the carbureter.

Baffle - plate. A partition or metal plate used to stop or deflect the flow or force of any matter.

Balance-weight. A weight fastened to a wheel or crank in order to balance the moving parts or to overcome the tendency to stop on dead-center.

Ball-bearing. A bearing which contains revolving spheres of hardened steel to lessen friction.

Ball-cage. A metal ring or other device which holds the ball of a ball-bearing in position.

Ball Check-valve. A check-valve in which a ball rests over the opening and keeps it closed against the flow of liquid or other matter in one direction, but which lifts and allows the material to pass when flowing from the opposite direction.

Ball-pein. The round end of the head of a machinist's hammer.

Ball-race. Steel disks or rings against which the balls of a ball-bearing travel.

Bearings. The portion of a mechanism upon which a revolving surface rests or with which it is in contact.

Bed. The surface or foundation on which an engine or machine rests.

Bed-plate. The flat surface on a motor-base by which it is attached to its bed.

Bell-crank. An angular piece supported by a pivot for transmitting motion or pull at right angles.

Bevel-gears. Wheels or gears with sloping edges or faces for transmitting motion or power at an angle.

Binding-post. The metal object to which electrical wires are attached. Usually equipped with a screw or clamp for holding the wires firmly in position.

Boxes. The casings or caps which hold bearings in position.

Brasses. Bearings of bronze or brass used in place of babbitt.

Breaker. A mechanical device for breaking the electrical current.

Break-spark. A spark produced by breaking or suddenly interrupting an electrical current.

Brush. Points or pieces of carbon, metal, etc., used to gather and transmit electricity, especially in a magneto or dynamo.

Burr. A rough or enlarged edge on a piece of metal.

Bushing. A thin casing or cylinder used to reduce the size of a hole or to enlarge an object placed in a hole.

By-pass. The opening or passage through which the gas passes from the base to the firing-chamber of a two-stroke motor.

C

Calorific Power. The actual amount of power contained in a heat-unit.

Calorific Value. The amount of heat-units contained in a definite amount of fuel.

Cam. A piece of metal of irregular shape attached to a shaft and designed to transmit a varying motion or power.

Cambered. Cut away or bent inward. Usually applied to frames where they are narrowed at the front end.

Cam-gear. The gear for operating cams.

Cam-shaft. The shaft to which cams are attached.

Cap-screw. A screw with a straight, not tapered, thread and a square or hexagonal head.

Carbureter. A mechanical apparatus for combining liquid fuel and air to form a gas.

Castellated Nut. A nut having notches or grooves in its top to hold cotter-pins.

Catalytic Ignition. A system of ignition in which spongy platinum is used. This material has the property of becoming incandescent when in contact with coal-gas or carbureted air.

Centrifugal. From the center outward.

Centrifugal Governor. A device for regulating speed by the centrifugal force of weights which swing outward when they reach a certain speed.

Centrifugal Pump. A pump which forces liquid by means of a revolving fan or wheel within a casing, the liquid being forced from the center outward.

Chassis. The frame with cross members, axles, and other parts of a motor-vehicle without the body.

Check-valve. A valve so arranged as to permit the flow of material in one direction, but not in another.

Clearance. The distance or space between two objects, especially the distance between the top of a piston at the limit of its upward stroke and the top of the cylinder.

Clutch. A mechanical device for holding power or motion between the motor and the driven mechanism, and so arranged that it may be released or thrown off at will.

Coil. Wire wound about an iron core to create a greater intensity in an electrical current.

Columbia Locknut. A form of nut with a tapered, threaded bushing within, so arranged as to contract or grip the thread upon which it is screwed and thus prevent working loose or slipping.

Combustion-chamber. The space in the cylinder, or connected with it, in which the gas is exploded or ignited.

Commutator. A device which revolves or oscillates, and through the action of which electricity is transferred from the armature to the wires of a magneto or dynamo. Also sometimes applied to a timer.

Compression-cock. (*See* Relief-cock.)

Compression-stroke. The stroke of a piston which compresses the gas in the cylinder.

Concentric Valve. A form of

valve in which one valve operates within another.

Condenser. A device consisting of numerous sheets of tin-foil and alternating with insulating material designed to reduce primary sparking and increase the secondary current in a coil.

Connecting-rod. The arm or rod connecting the piston with the crank-shaft.

Contact-points. The points through which an electrical contact is made. Platinum points on the vibrator or the electrodes of a make-and-break system.

Cotter-pin. A pin with the two ends bent around so as to lie close together. When placed in a hole the ends are separated to prevent the cotter-pin from working out.

Counterweight. (*See* Balance-weight.)

Counterbalance. Same as above.

Coupling. A device for connecting two rods, pipes, or shafts.

Crank. The part of shaft to which the connecting-rod is attached. The handle used for turning a motor when starting.

Crank-case. The case or chamber within which the shaft and cranks revolve.

Crank-shaft. The shaft bearing the crank.

Cross-heads. A piece to which a connecting-rod is attached at its upper end and to which the lower end of the piston-rod is fastened and which slides in grooves. Used to transmit straight, linear motion to a crank, or *vice versa*.

Current-breaker. A mechanism for breaking or interrupting an electrical current.

Cut-out. A device for allowing the burned gases to pass into the air without entering the silencer.

Cycle. A definite period of time in which certain events occur regularly. When applied to a motor it is practically the same as "stroke," and is equal to approximately one-half of a revolution of the shaft or fly-wheel.

Cyclic Phases. The changes or phases which occur during each cycle or stroke of a motor.

Cylinder. The portion of a motor which contains the piston, and within which the gas is ignited or exploded. Any circular, hollow object.

Cylinder Ribs. Metal ribs or projections on a cylinder's surface used to radiate heat and keep the cylinder cool in air-cooled motors.

D

Dead-center. The portion of a revolution of a shaft during which the crank is at its upward or downward limit, so that force exerted against it does not exert a leverage to revolve it.

Deflector. The projection on the top of a two-cycle piston used to prevent the incoming charge from passing directly out by way of the exhaust-port. Any plate or object designed to direct or turn the flow of gas or liquid.

Diaphragm. A thin partition, usually flexible.

Die. A tool for cutting screw-threads on rods or pipes. Also a stamp or press for cutting anything or for forming definite shapes.

Die-stock. A holder for using dies.

Differential. Gears or wheels so arranged that motion or power may be transmitted at various speeds or powers or to transmit power or motion where the resistance is unequal.

Differential-cam. A cam transmitting varying power or motion.

Differential-piston. A piston with the lower portion of larger size than the upper and so arranged that the two portions operate together to perform separate functions. Two pistons arranged together for the same purpose.

Distance-rod. The rod connecting the two front wheels of a motor-vehicle to keep them a definite distance apart.

Distillate. Certain grades of petroleum fuels. Denatured alcohol.

Distributer. A device for dis-

tributing anything. In motor parlance usually applied to a device for distributing the electrical current to the various cylinders.

Dog. A mechanical device for transmitting certain motions. A device for holding material in a lathe. Metal projections.

Dowell. A pin or piece of metal for holding two parts together.

Drag-link. A short rod connecting the steering mechanism of a vehicle to the front wheels.

Drop-ell. An elbow fitting with a bracket as above.

Drop-tee. A form of pipe connection in the form of a tee and provided with a bracket for attaching it to another object.

Dynamo. A machine for producing electricity by the revolution of an armature between electromagnets.

Dynamometer. An instrument for determining the power required to operate a machine at a certain speed.

E

Eccentric. A circular disk on a shaft set off-center and used to transform rotary motion to reciprocating motion.

Eddy Current. A flow of gas caused by rough corners in the passages which prevent the free and regular flow from or to the cylinder.

Electrodes. Two points between which a spark occurs, as in a spark-plug.

Electrolysis. The action of two metals—as copper and iron—when immersed in a liquid by which an electrical action is established, thus corroding or eating away one of the metals.

Electrolyte. The material used for filling a battery and in which the two elements, as carbon and zinc, are immersed.

Electromagnet. An iron core wound with wire. When electricity passes through the wire the iron becomes magnetic.

Exhaust. The escape of used or burned gas from the cylinders. The aperture through which the exhaust-gases pass.

Exhaust-valve. The valve which opens to allow exhaust-gases to escape.

Expansion-joint. A coupling or joint so arranged as to permit of expansion and contraction by one portion of the joint sliding over the other.

F

Face. Any smooth or flat surface.

Faced Joint. A joint composed of two smooth or faced surfaces.

Face - plate. A device provided with clamps or bolts designed to hold objects in a lathe so that they may be turned off or "faced."

Fan. A wheel or disk with blades or paddles for circulating air. Sometimes wrongly applied to a propeller-wheel.

Feather-vibrator. A particular type of vibrator capable of very rapid vibration and usually of thin or delicate construction.

Fixed Spark. A spark set or fixed to occur at a certain time. A "set spark."

Flange. A ridge or projection, especially applied to two such parts designed to be bolted together or attached to some other object.

Flange-coupling. A coupling for joining two pipes or shafts and held in place by two flanges bolted together.

Flange-union. The same as above when used for pipe.

Flash-point. The temperature at which a substance ignites.

Flexible Coupling. A coupling so designed as to allow the two connected parts to revolve even when out of line or at an angle.

Flexible Elbow. An elbow-joint designed as above.

Flexible Joint. Same as above, but more applicable to small rods, etc.

Flexible Union. A union or connection for pipes constructed with parts so designed as to permit the pipes being set at various angles.

Float-feed. A float connected with a valve in such a way as to con-

trol the flow of a liquid by the depression or lift of the float.

Flooding. An excessive amount of liquid fuel in the motor or carbureter.

Fly-wheel. The large wheel at the end of a shaft.

Four-cycle. The operation of a motor in which an explosion occurs only on every fourth stroke, or second revolution.

Four-stroke. Same as above.

Friction-clutch. A clutch in which the motion or power is transmitted by friction.

Friction-drive. A method of power transmission through frictional resistance. Usually between two friction wheels or disks.

G

Gage. A device or instrument for measuring anything.

Gap. The space through which a spark passes between two electrodes.

Gasket. A ring of material placed between two surfaces to make a tight joint.

Gate-valve. A form of valve which has a gate or partition which may be raised or lowered. A full-way valve.

Gear. A cog-wheel or a combination of cog-wheels. Any device for transmitting power, speed, or motion through the medium of cog-wheels.

Gear-pump. A pump in which the liquid is forced or drawn by means of interlocking gears within a case.

Generator. A device for generating anything, especially a form of carbureter.

Gland. A thimble or ring of metal used to secure packing in position.

Globe Valve. A valve which operates by a circular or globular piece resting upon a seat and operated by means of a stem with a screw-thread.

Governor. A device for automatically regulating speed, power, or flow within certain definite limits.

Gravity-feed. Feeding oil or other material by gravity alone.

Gravity-oiler. A device for feeding oil by gravity.

Ground. The frame or other portion of a motor to which one of the primary electrical wires is attached.

Grounding. Connecting one wire to a "ground" so as to use the metal in place of a wire.

H

Hammer-break. A type of breaker or interrupter which operates much like a hammer striking upon a piece of metal.

Hammer-vibrator. A vibrator constructed to give slower and stronger vibrations than other forms.

Hanger. A support for holding a shaft. Usually attached to a wall or ceiling and equipped with bearings.

Hanger-bolt. A lag-screw with one end threaded for wood and the other to receive a nut so that it is not necessary to remove the screw from the wood in order to remove the object which the screw holds or supports.

Helical Gear. A cog-wheel with the teeth slanting or curved so that they form a section of a coil or helix.

Helical Spring. A spring in the form of a helix. A coil-spring.

High Tension. An electrical current of high amperage or voltage. The induced current in an induction-coil. The secondary current.

Horse-power. The power or force required to lift 33,000 pounds 1 foot in 1 minute.

Hot Tube. A device for igniting the charge of gas by a red-hot tube or rod.

Hunting. The irregular action of a governor causing a motor to vary its speed at intervals.

Hydrometer. An instrument for determining the specific gravity of liquids.

I

Igniter. Any device for igniting the explosive charge of gas.

Ignition. The process of igniting the gas.

Ignition-plug. The spark-plug.

Indicator. A device for determining the action of an engine by a tracing on a card.

Inductance. The mysterious power of inducing or generating a current of electricity in a coil of wire by passing a current through another coil not in contact with it, or by plunging a magnet back and forth within a coil of wire, or by revolving a coil of wire between two magnets.

Induction-coil. A coil for inducing electricity.

Inertia. The tendency of any object to remain stationary when at rest and which must be overcome before it starts to move.

Inertia-governor. A governing device which depends upon inertia for its operation.

Inlet-valve. The valve which admits the charge of gas to the cylinder.

Insulation. The covering or protection of electrical conductors to prevent escape of electrical currents.

Insulator. Anything which prevents the electricity from escaping.

Intake. The opening through which fresh gas enters the motor.

Intake-stroke. The stroke of a piston which sucks a charge of gas into the motor.

J

Jacket. A covering outside of the cylinder, with an intervening space for the circulation of liquid for cooling the motor.

Jig. A device by which any machined object may be accurately duplicated.

Journal. A bearing on a shaft.

Jump-gap. The same as spark-gap.

Jump-spark. A spark of high-tension electricity between two electrodes. The system of ignition using the jump-spark.

K

Key. A square metal piece inserted between a wheel or similar object and its shaft and fitting into grooves in each to prevent one from turning on the other.

Keyway. The recess or slot into which a key fits.

Kicking. Back or premature firing causing the motor to reverse its motion or to "kick."

Kilometer. A unit of the metric system for measuring distances, and equal to five-eighths of a mile.

Kiss-spark. A form of make-and-break spark in which the contact is made gradually, the points press firmly together, and separate suddenly. Also known as "butt-spark."

L

Lag-screw. Heavy wood-screws with square bolt-heads.

Lead. The advance of the timing of a spark so as to produce ignition before the limit of the upward or compression stroke.

Lever. A rod or arm for transmitting, increasing, or controlling power or motion.

Liners. Thin pieces of metal or other material for reducing or increasing the space between two objects.

Lock-nut. A nut screwed onto a bolt above the regular nut to prevent the latter from working loose.

Lock-washer. A washer or ring used beneath a nut to prevent it from working loose.

Lost Motion. Any motion which accomplishes no useful purpose. Looseness which allows a waste of speed or power.

Low Tension. The primary electrical current, as from a battery, magneto, or low-tension coil.

Lubricator. Any device for distributing oil.

Lug. A metal projection for attaching to another object or to rest or bear against another piece.

M

Magneto. A mechanical device for generating electricity by means of

a coil or armature revolving between permanent magnets.

Make-and-break. An ignition system in which the sparks are produced by alternately making and interrupting a low-tension current.

Manifold. The common outlet of several pipes or tubes.

Manometer. An instrument for determining the pressure of gases.

Mechanical Equivalent. The power actually contained in a gas and which must be accounted for either as heat taken from it or in some form of mechanical energy. A deduction from the law that nothing in nature can be lost or wasted.

Mechanical Oiler. A lubricating device operated mechanically.

Momentum. The tendency of any object to continue moving after the force required to move it has ceased.

Motor. Any machine for producing power or for transforming natural forces into mechanical motion.

Muffler. An appliance for quieting or silencing the noise of the exhaust.

N

Needle-valve. A valve composed of a pointed rod, bearing against the circumference of a hole.

Nipple. A short piece of threaded pipe.

O

Offset-cylinder. A cylinder placed in such a way that its center is at one side of the center of the shaft.

Offset-crank. A crank so placed that its center is out of line with the cylinder center.

Ohm. A unit of electrical measurement used to denote resistance. Almost analogous to "friction."

Otto Cycle. Same as "four-cycle," so called because the Otto engine was the first to successfully employ this system.

P

Packing. Any material used to prevent leakage around a joint or opening, especially around a moving object such as a pump-piston, shaft, etc.

Packing-gland. A piece of metal used to secure packing in position.

Packing-nut. A nut to hold packing in place.

Pawl. A dog or piece of metal arranged to fit into a notch. (*See* Ratchet.)

Pein. The end of a hammer-head used for striking.

Peining. Hammering or stretching a piece of metal by use of the pein of a hammer.

Pendulum-governor. A governing device which operates by the swing of a pendulum instead of by centrifugal force.

Pick-blade. A small blade of metal which lifts the valve in a pick-blade governor.

Pick-blade Governor. A governor that raises the valve-stem by a pick-blade when under excessive speed.

Pillow-block. A stand or support to hold a journal or bearing.

Pinion. A small cog or gear wheel. Properly a wheel with pins or posts instead of cogs.

Piston-pin. The pin which holds the connecting-rod in the piston.

Piston-ring. A ring fitted loosely around the piston and which by its spring or elasticity forms a gas-tight joint with the cylinder.

Pitman. Same as connecting-rod.

Pitting. Wear or corrosion in the form of small holes or depressions.

Planetary Gear. A gear constructed with several wheels or pinions revolving around a common center.

Planimeter. A device for ascertaining the area of indicator diagrams.

Plunger. A piston. An object sliding within a cavity formed to fit closely about it.

Plunger-pump. A pump operating by means of a plunger or piston.

Port. An opening through which gas is admitted to the cylinder or base of a motor or an opening from one cavity to another.

Preignition. Premature ignition or explosion of gas.

Primary Coil. A coil for producing low-tension electricity.

Primary Winding. The first winding on a spark-coil and that which conveys the primary, or low-tension, current.

Primary Wire. Wire for conveying primary, or low-tension, electricity.

Priming. Injecting liquid fuel into a motor cylinder to start it or placing water or other liquid in a pump for starting.

Priming-cup. A receptacle or cup connected with a cock or valve and placed on the cylinder for the purpose of admitting liquid fuel for priming.

Progressive Gear. A form of change-speed gear in which the operating lever moves in a straight line.

Prony Brake. A device for testing the power of motors.

Protractor. An instrument for determining angles and degrees of a circle.

Puddle-carbureter. A type of carbureter in which the liquid fuel is in a pool or puddle instead of in a float-chamber and from the surface of which the gas is drawn.

Pyrometer. An instrument for testing the heat of exhaust-gases.

Q

Quadrant. A piece of metal in the form of a quarter-circle, usually applied to a notched piece which holds levers in place.

R

Rack. A notched or cogged bar operated by or operating a cog-wheel or pinion to transform rotary to linear motion, or *vice versa*.

Rack and Pinion. The combined rack and wheel.

Radiator. A device for radiating or giving off heat.

Radius-rod. A rod or bar arranged to hold two objects at a definite distance apart. Usually the rods connecting the real axle of a vehicle to the frame or body.

Ratchet. A device by which a wheel may turn one way and not the other.

Ratchet-valve. A valve operated by a ratchet-gear instead of by cams.

Ratchet-wheel. A wheel or disk with notches so formed that it will turn in one direction but is prevented from turning in the other direction by dogs, or "pawls," which drop into the notches.

Ratio. The proportion or relation of one thing to another.

Reducer. Any device for reducing the size of an opening or of a rod or shaft.

Reducing-coupling. A coupling smaller at one end than at the other.

Reducing-elbow. A pipe elbow with one opening larger than the other.

Relief-cock. A cock or valve to relieve or decrease pressure.

Retarded Spark. A spark occurring after the piston has commenced to descend.

Ribbon Vibrator. A form of vibrator made with a slender or thin piece of metal to which is fastened the contact-point.

Ring-oiler. An oiling device composed of a hollow ring on the shaft and which distributes the oil by centrifugal force.

Ring-valve. A valve in the form of a ring or cylindrical section.

Rocker-arm. An arm or lever working on a pivot and moving in a rocking manner.

Rotary Motor. A motor in which the cylinders revolve around a stationary shaft.

Rotary Valve. A conical, cylindrical, or disk-like valve which rotates or revolves on its seat without lifting.

Ruhmkorff Coil. An induction-coil.

S

Scavenging. Cleansing the cylinder of burned gases.

Secondary Coil. An induction-coil.

Secondary Current. The high-tension or induced current.

Secondary Winding. The outer coil of wire of an induction-coil and which carries the secondary current.

Secondary Wire. Wire which carries the high-tension or secondary current.

Selective Gear. A type of gear shift in which the operating lever moves in both a lateral and longitudinal direction, according to the speed desired. A "sliding-gear."

Self-oiling. Oiling without the aid of mechanical devices.

Self-starting. Provided with mechanical means of turning the engine for starting.

Set-screw. A screw for holding a shaft or similar object in position.

Set-spark. A magneto or other device so arranged that the spark occurs at a definite time in relation to the piston and which cannot be varied or "advanced" at will.

Shaft. Any revolving-rod for transmitting motion or power.

Shims. Thin pieces of metal placed between the two halves of a joint to separate them and adjust the space. (*See* Liners.)

Short Circuit. The passage of electricity from one point to another without passing through the conductor designed for it.

Sight-feed. An arrangement by which the amount of oil flowing from a lubricator may be seen.

Silencer. A device for quieting the sound of the exhaust. A muffler.

Skew-gear. A gear in which the cogs are at an angle to the shaft.

Sliding-gear. A gear-shift in which the various gear-wheels slide out and into mesh on shafts or axles. Usually a selective gear.

Sonoscope. An instrument for determining the location of a pound or noise in a motor.

Spark-coil. A secondary or primary coil used for increasing the intensity of the electrical current.

Spark-plug. A plug fitted into a cylinder and at the terminals of which the spark for igniting the gas is produced.

Sparking-points. The electrodes, or terminal points, at which the spark occurs.

Spider. A device with several arms or extensions for holding any object in place by means of a screw passing through its center.

Spindle. A round rod or bar. A short shaft. The tapered end of a rod or shaft.

Sprocket. A wheel with teeth which fit into links of a chain for transmitting motion or power.

Sprocket-chain. The chain used in connection with sprockets.

Spur-gear. A form of gear-wheel in which the teeth are sharp or pointed.

Street-elbow. A pipe elbow in which one end has male and the other female thread.

Stub-gear. A form of gear-wheel with teeth with blunt square ends.

Stud. A piece of projecting metal threaded for a nut. A lug.

Stud-bolt. A bolt threaded at both ends so that it may be screwed into a hole and a nut afterward screwed onto the projecting part.

Stuffing-box. A box or case through which a shaft passes and which may be packed to prevent leakage around the shaft.

Suction-stroke. The stroke of the piston which draws in the charge of gas. The intake stroke.

Switch. A device for turning on or off the electrical current.

T

Tachometer. A device for determining the number of revolutions of an object.

Tap. A tool for cutting female threads.

Taper-pin. A pin used to hold two parts of a machine together.

Templet. A pattern or guide for duplicating objects.

Terminal. The end of a wire or electrical connection.

Thermal. Relating to heat.

Thermal Efficiency. The proportion of heat used by the motor, as indicated by the power developed, as compared with the total heat contained in the fuel used.

Thermal Units. The amount of heat required to raise one pound of pure water from 32 degrees to 33 degrees Fahr.

Thread. A spiral groove cut in a hole, on a screw or on a pipe, rod, or other object in order that it may be screwed into a hole cut with a corresponding thread.

Throttle. A device for controlling the speed of a motor by regulating the amount of fuel used.

Thrust. The forward push of a shaft when operating under a load. Any endwise force.

Thrust-bearing. A bearing designed to overcome friction of thrust.

Thrust-collar. A collar fitted to a shaft to prevent undue play caused by thrust.

Tie-bar. Same as distance-rod.

Timer. A device for interrupting and connecting the electrical current at fixed intervals.

Timing. Regulating or adjusting the timer, magneto, or cams to operate at the proper time in relation to the positions of the pistons.

Torque. A turning or twisting force.

Two-cycle. A type of motor in which an explosion takes place on every second stroke, or on every complete revolution. A two-stroke motor.

U

Underslung. A method of attaching the body and frame of a vehicle to the axles by placing the frame below the axles.

Union. A coupling for connecting pipes so that they may be separated or connected without disturbing the rest of the pipe.

Universal. A joint or coupling designed to allow movement in any direction.

V

Valve. A device for opening or closing a passage.

Valve-box. The casing in which a valve operates.

Valve-cage. The casing which contains the valve.

Valve-cam. The cam that operates the valve.

Valve-chamber. The chamber in which the valve is placed.

Valve-foot. The lower end of a valve-stem, upon which push-rods or cams operate.

Valve-gear. Gears for operating valves.

Valve-port. The opening through or beneath a valve which is opened and closed by its action.

Valve-release. A device for releasing or opening the valves to make starting easier.

Valve-rod. A rod that operates a valve.

Valve-seat. The portion of a valve-box upon which the valve rests when closed. In a rotary or sliding valve the casing around the valve and upon which it bears.

Valve-stem. The stem or spindle which connects a valve to its foot or handle.

Vaporizer. A device for vaporizing or transforming liquid fuel to a gas. A crude form of carbureter.

Venturi Tube. A tube or passage constricted, or narrowed, to give great speed or suction to air or other gas drawn through it.

Vibrator. The part of an induction-coil which automatically opens and closes the circuit.

V-motor. A form of gas engine in which the cylinders are placed at an angle with the shaft or in a V form.

Volt. A unit of electrical measurement denoting force. Nearly equivalent to "pressure."

Voltage. The amount of volts produced by an electrical generator.

Voltmeter. An instrument for determining voltage.

Vulcanizing. The process of

hardening rubber by heating it with sulphur.

W

Waste-nut. A flange or plate for attaching pipes to a floor or wall.

Water-jacket. The casing around a cylinder or other object and which contains water.

Web. The thin part of a wheel which connects the hub with the rim.

Wipe-break. A form of make-and-break spark in which the electrodes rub or wipe against one another.

Wire-drawing. The resistance or pull caused by overcoming friction or pressure against moving gas or in overcoming the resistance of a spring.

Woodruff Key. A form of key in which one edge is straight and the other semicircular. Used to hold gears or wheels to shafts where the end of a key cannot project.

Worm-cam. A cam with a "worm," or spiral grooves.

Worm-gear. A gear with a spiral groove, or "worm," in place of cogs.

Worm and Segment. A form of gear employing a worm-gear acting on a sector or quadrant, with cogs fitting in the grooves of the worm.

Wrist-pin. The pin which holds the connecting-rod to the cross-head. Commonly but improperly applied to the portion of the crank on which the connecting-rod bears.

INDEX

A

Advancing spark, 97.
Aeroplane motors, 119.
Air-cooled motors, 20.
Air-cooling, 20.
A. L. A. M. rating, 127.
Aligning wheels, 221.
Alternating current, 51.
Amperage, 49.
Ampere, 49.
Annular bearings, 86, 214.
Appendix, 265.
Arrangement of cylinders, 116.
Automobile ignition, 185.
Automobiles and their motors, 181.

B

Baffle-plate muffler, 140.
Ball-bearings, 85, 214.
Base, 77.
Batteries, 41.
Bearing-caps, 83.
Bearings, 81, 85.
Bearings and axles, 213.
Bedelia cycle-car, 228
Belt-fasteners, 165.
Belt-guides, 164.
Belt-lacings, 164.
Belt-tighteners, 164.
Bosch magneto, 188.
Box-coils, 60.
Brake-bands, 212.
Brake horse-power, 127.
Brakes, 212.
Breaker adjustments, 187.
Breaker-box, 187.
Breakers, 56.
Brushes, 54.
Burn-Boston batteries, 46.

C

Cages, 85.
California cycle-car, 231.
Cam-gear, 14.
Cams, 14.
Carbureter adjustments, 195.
Carbureters, 34.
Care and handling of marine motors, 148.
Carnation cycle-car, 230.
Centrifugal pumps, 26.
Circulating the water, 24.
Clutches, transmissions, etc., 200.
Commutators, 53.
Comparison of two and four cycle motors, 15.
Compression-plate, 106.
Compression-stroke, 7, 14.
Condensers, 59.
Conductors, 47.
Cone-clutches, 205.
Connectors, 68.
Couplings, 139.
Crank-cases, 77.
Cup and cone bearings, 86, 214.
Cycle-cars, 226.

D

Dash-coils, 60.
Dead-centers, 90.
Delivered horse-power, 126.
Diesel motor, 39.
Differentials, 171, 209.
Direct current, 50.
Distance-rods, 218.
Distributer, 189.
Distributer valve, 113.
Drag-link, 218.
Driving-gear, 14.
Dry batteries, 46.

E

Economy car, 230.
Ejector muffler, 141.
Electrical currents, 50.
Electrical equipment, 46.
Electrolytic, 51.
Elmore motor, 113.
Emergency brakes, 212.
"En bloc" cylinders, 76.
Equalizers, 213.
Exhaust-stroke, 14, 87.
Exhaust-valve, 14.
Expansion-chambers, 140.
External contracting-brake, 212.

F

Fans, 20.
Fins, 20.
Firing sequence, 97.
Firing-stroke, 7, 14.
Flange coupling, 139.
Float-feed carbureter, 36.
Foot-brakes, 212.
Force-feed oiler, 32.
Four-cycle motor, 12.
Four-stroke motor, 12.
Friction-disk clutches, 205.
Friction-drive, 206.
Friction-load, 126.
Full-floating axles, 216.

G

Gas engines, 34.
Gaskets, 250.
Gear-pumps, 26.
Glossary of technical terms, 277.
Gnome motor, 122.
Governors, 154.
Gravity-feed oilers, 30.
Ground-wire, 63.
Gyro motor, 122.

H

Hand-brakes, 212.
Handy hints and emergency repairs, 256.
Hangers, 162.
High-tension currents, 51.
High-tension magnetos, 56.
Hit-or-miss governors, 155.
Hopper-cooled motors, 23.
Horizontal motors, 154.
Horse-power, 125.
How batteries and magnetos produce electricity, 51.
How motors are oiled, 28.
How the gas is exploded, 39.
Hyatt bearings, 215.
Hydrex silencer, 142.

I

Idler-gears, 88.
Imp cycle-car, 231.
Indicated horse-power, 126.
Induced current, 53.
Induction-coil, 57.
Installation of marine motors, 145.
Installing stationary motors, 166.
Insulation, 60.
Intake-stroke, 14.
Intake-valve, 14, 87.
Internal-expanding brakes, 212.
Interrupters, 58.
Introduction, 1.

J

Joe's gear, 136.
Jump-spark, 39, 41.
Justrite motor, 123.

K

Keeping motors cool, 20.
Kingston carbureter, 199.
Knight motors, 107.

L

Leather-faced clutches, 205.
L-head motors, 92.
Limit-gages, 74.
Locating ignition troubles, 192.
Low-tension currents, 51.

M

Magnetic field, 53.
Magnetic inductance, 53.
Magnetic phantom, 54.
Magnetos, 41.
Magnetos and dynamos, 52.
Make-and-break ignition, 39, 42.
Marine and stationary motors, 131.
Marine gears, 135.
Marine motors, 133.
Mechanical efficiency, 126.
Mechanical mixing-valve, 38.

INDEX

Mechanical vaporizers, 37.
Mechanically operated valves, 14.
Mixing-valve, 35.
Motor anatomy, 72.
Motor-cycles, 224.
Motor troubles and remedies, 265.
Mufflers and silencers, 139.
Mushroom-valves, 88.

N

Non-conductors, 47.

O

Ohms, 50.
Oil-cooling, 20.
Oiling through fuel, 29.
One-way clutch, 137.
Open-base motors, 106.
Opposed-cylinder motors, 116.
Otto cycle, 12.
Otto gas engine, 12.
Overhauling, 239.
Overhead valves, 92.

P

Parts of two-cycle motor, 9.
Pillow-blocks, 162.
Piston-rings, 16, 19.
Piston-valve motors, 110.
Planetary gears, 200.
Plug-coils, 61.
Plunger pumps, 26.
Poppet-valves, 87.
Position of valves, 92.
Potential, 48.
Power transmission, 157.
Preventing troubles, 237.
Progressive gear, 201.
Push-rods, 14, 88.

R

Races, 85.
Radial motors, 116.
Radiators, 23.
Rayfield carbureter, 198.
Remy magneto, 190.
Retarding-spark, 97.
Roller-bearings, 85, 215.
Rotary pumps, 26.
Rotary-valve motors, 111.
Rotating-motors, 116, 122.

S

Schebler carbureters, 196.
Selective gears, 202.
Semi-floating axles, 217.
Service brakes, 212.
Shafts and bearings, 81.
Shafts and universals, 137.
Shims, 83.
Shunt current, 54.
Simple wiring, 62.
Single and multiple cylinder motors, 73.
Six-cycle motors, 5.
Size and power of motors, 125.
Skew-toothed gears, 88.
Sleeve-couplings, 139.
Sleeve-valve motors, 107.
Some electrical terms explained, 47.
Source of electricity, 46.
Spark-coils, 41, 57.
Spark-coils and wiring, 60.
Spark-plugs, 41.
Special forms of motors, 105.
Sprockets and chains, 88.
Spur-gears, 88.
Star motors, 116.
Stationary motors, 153.
Steering-columns, 218.
Steering-gears, 218.
Storage batteries, 47.
Stromberg carbureters, 199.
Stuffing-boxes, 137.

T

Table of troubles and remedies, 266.
Tappets, 88.
T-head motors, 92.
Thermex silencers, 142.
Thermo-siphon system, 24.
Three-port motors, 7.
Throttling-governors, 155.
Thrusts, 85.
Tight-and-loose pulleys, 162.
Timers, 41.
Timpkin bearings, 215.
Tools and supplies, 253.
Troubles and repairs, 235.
Two boys and a motor, 172.
Two-cycle motors, 5.
Two-port motors, 7.
Two-stroke motors, 5.
Twombly cycle-cars, 231.
Types of cycle-cars, 230.

U

Unit coils, 60.
Universal joints, 138.

V.

Valves, 86.
Valve-springs, 14.
Valve-timing, 88
Vaporizers, 34.
Varying-ignition governors, 155.
Vehicle motors, 179.
V-form motors, 116.
Vibrators, 58.
Voltage, 48.
Volts, 48.

W

Water-cooled motors, 21.
Water-cooling, 20.
Water-jackets, 22.
Wet batteries, 46.
What a gas engine is, 3.
What makes the power, 34.
Worm-gears, 88.

Y

Yankee muffler, 141.